NUI Galway
OÉ Gaillimh

School of Mathematics, Statistics and Applied Mathematics

Eleventh Research Day

12 May 2021

Programme

	Talks take place on Zoom. Coffee, lunch, posters and reception take place on Gather.
9:20–9:30	Welcome by **Aisling McCluskey**, Head of School
9:30–9:40	Opening by **Becky Whay**, Vice President International
9:45–10:15	**Valentina Balbi (NUI Galway)** *The mechanics of a* twisted *brain*
10:15–10:45	**Simone Coughlan (NUI Galway)** *Exploring the Gut Virome in Irritable Bowel Syndrome*
10:45–11:30	**Coffee (Gather space)**
11:30–12:00	**Martin Kerin (NUI Galway)** *Simply closed geodesics on fake Cayley planes*
12:00–13:00	**Research blitz (Organiser: Mark Howard)** Harold Berjamin: *Nonlinear acceleration waves in soft porous media* • Bharat B. Tripathi: *Formation of Shear Shock waves in Human Head Phantom for Traumatic Brain Injury* • Hannah Conroy Broderick : *Waves in dielectric plates* • Angela Carnevale: *Board games 2.0* • Cian O'Brien: *Maximising the Number of Equal Entries in Alternating Sign Hypermatrix Latin-like Squares* • Michael McGettrick: *Some interesting sequences arising in Bayesian games over* $\mathbb{Z}_n$
13:00–14:00	**Lunch (Gather space)**
14:00–14:45	**Ann O'Shea (Maynooth University)** *The role of mathematical tasks in the transition to university*
14:45–15:15	**Carl Scarrott (NUI Galway)** *Not a walk in the park(run)*
15:15–17:00	**Poster session (Organisers: Aoife Hill, Róisín Hill).** **Reception and poster prizes** (Gather space)

Contents

1 Introduction

Fáilte chuig an ócáid speisialta seo ag ceiliúradh chúrsaí taighde inár scoil.

Welcome to this historic celebration, our 2021 Research Day in the School of Mathematics, Statistics and Applied Mathematics. This year's event is distinctive not only through the wealth of achievements and contributions of our research community across two years but also through their manifestation against an ongoing world pandemic. We last celebrated our 'annual' Research Day in April 2019. One year on, all had changed utterly. This booklet demonstrates the strength, resilience, and creativity of our community in not just carrying on against the odds but in excelling. We can look back and be proud; we can look forward and be excited by the promise of new developments and fresh aspirations.

The energy and ambition inherent in our research success is matched by the energetic and dedicated team of colleagues Andrew, Tobias, Mark and research students Róisín and Aoife who have organised today's event and to whom we are especially grateful.

Today's programme of talks and poster exhibition highlights the quality, the breadth, and the international significance of the research activities in each of our disciplinary clusters: the Biostatistics & Bioinformatics Cluster, the Stokes Cluster for Applied Mathematics, and the de Brún Centre for Mathematics. Today's event showcases the indefatigable spirit of our research community and especially of our research students, who have for 13 months and counting been without their normal research infrastructure of office, library and campus interaction.

Some highlights spanning the last two years:

- We welcomed eight new academic staff members to the School, joining us from recent positions in the U.S, Germany, Ireland and New Zealand: Valentina Balbi, Angela Carnevale, Simone Coughlan, Mark Howard, Martin Kerin, Stephan Rudykh, Carl Scarrott and Bharat Tripathi.

- We welcomed nine new postdoctoral researchers: Harold Berjamin and Bin Wu (working with Michel), Hannah Conroy Broderick (working with Stephan), Cian O'Brien (working with Rachel), Dúalta Ó Fionnagáin (working with Aaron), Jeremy Rodriguez (working with Mark), Davood Roshan and Thiago Oliveria (working with John N) and Patrick Staunton (working with Cathal).

- The vibrancy of our PhD programmes continued unabated. We were proud to celebrate ten successful PhD defences in our School: Jaynal Abedin, Nisreen Alokbi, Isaac Burke, Richard Burke, Hannah Conroy Broderick, Roberto Galizia, Vinh Quang Mai, Cian O'Brien, Nghia Tran and Michael Welby. Sincere congratulations to all our graduates – we wish them every success in the next phase. We extend a warm céad míle fáilte to our 21 new students who commenced their PhD studies with us in the same period.

- We published extensively in world-class journals including the notable Annals of Mathematics (Martin Kerin with collaborators K. Shankar and S. Goette).

- We had phenomenal funding success encompassing 14 grants amassing of the order of €6m, including an ERC Starting Grant (€2m Stephan Rudykh).

- We hosted four conferences and one workshop on campus: the 42nd annual Groups in Galway meeting in May 2019, the Irish Mathematical Society meeting in September 2019, the inaugural conference marking the launch of the SFI Centre for Research Training (CRT) in Genomics Data Science also in September 2019, the Irish SIAM Student Chapter conference in December 2019 and the 5th Annual Stokes Modelling Workshop in May 2019. Adapting to the prevailing circumstances, we also hosted online the 43rd Groups in Galway meeting in September 2020, the 6th Annual Stokes Modelling Workshop in June 2020 and the annual CRT Research Symposium December 2020.

Referring to the above highlights, there is a sense of 'follow that' ... and we will. But today we pay tribute to our collective research efforts during a time that will go down in history. We celebrate our collective research successes as we drive our research mission ever forward. We acknowledge the role of our administrative and technical staff in supporting our mission, and we look forward to further productive and fulfilling research experience in the coming months. Enjoy this landmark Research Day – it is a tribute to us all.

Aisling McCluskey
Head of School

2 Abstracts of talks

Valentina Balbi (NUIG): *The mechanics of a* twisted *brain*

Abstract: Biological soft tissues are particularly common in nature. For instance, many organs in the human body such as the skin, the brain, the gastrointestinal system are made of soft tissues. The brain, among all is particularly soft and delicate. Following an impact to the skull, brain matter can experience large stretches, possibly resulting in Diffuse Axonal Injury (DAI), which is the second leading cause of death from traumatic brain injury. Previous studies have focused on linear (uni-axial) stretches of brain to investigate DAI, but in reality brain matter undergoes a mix of deformation modes during an accident. This talk will focus on the mechanical behavior of the brain under torsion (twisting). In collaboration with University College Dublin, we collected data from torsion tests on (pigs) brain samples and modelled the experiments to finally quantify the elastic properties of the brain tissue. I will show that torsional impacts, such as a hook punch in boxing and a side impact in a car accident can also lead to dangerous levels of stretch compatible with DAI.

Simone Coughlan (NUIG): *Exploring the Gut Virome in Irritable Bowel Syndrome*

Abstract: Irritable Bowel Syndrome (IBS), the most common gastrointestinal disorder, is diagnosed solely on symptoms. Potentially diagnostic alterations in the bacterial component of the gut microbiome (the bacteriome) are associated with IBS, but despite the known role of the virome (particularly bacteriophages), in shaping the gut bacteriome, few studies have investigated the virome in IBS. In this presentation, I will discuss the results of a research project that used metagenomic sequencing of the gut virome in patients with IBS and healthy control individuals to characterise how the gut virome of IBS patients differs from those without IBS, as well as challenges that I encountered in this project.

Martin Kerin (NUIG): *Simply closed geodesics on fake Cayley planes*

Abstract: If you pick any point p on a compact, rank-one symmetric space (CROSS; e.g. a round sphere), it is well known that all geodesics emanating from that point will return (smoothly) to the point p at the same time and without any prior self intersections. A classical problem in Riemannian geometry is to classify all Riemannian manifolds which satisfy this nice property. While explicit non-CROSS examples do exist, they are difficult to find. In this talk, I'll describe a classical construction which should yield infinitely many examples among fake Cayley projective planes and, if time permits, indicate why this project is as yet unfinished. This is joint work with Chao Qian.

Ann O'Shea (Maynooth University): *The role of mathematical tasks in the transition to university*

Abstract: In this talk I will report on the views of first-year university students on the differences between mathematics at school and at university, and on the changes to their study methods as they make the transition to university mathematics. I will also consider their views on the differences and affordances of tasks that they encounter on either side of the transition. I will explore the role that mathematical tasks have in making lecturers' expectations clear to students, as well as in giving students' opportunities to develop mathematical thinking skills and work independently. This is joint work with Sinead Breen (DCU).

Carl Scarrott (NUIG): *Not a walk in the park(run)*

Abstract: parkun is a relaxed community orientated event where participants can turn up every Saturday to walk, jog or run, which is organised by dedicated volunteers. The events have expanded from its origins in the UK to 20 countries around the world, with a notable growth in the diversity of the participants due to the accessibility and inclusiveness of the events. The increased diversity has led to an increase in the absolute number and rate of serious life-threatening incidents events over time.

This observational study will examine the 29.5 million participations by over 2 million distinct runners and the 84 serious life threatening incidents that occurred in the UK over a 6 year period. The aim is to quantify the impact of risk factors on the likelihood of such serious incidents (gender, age, running experience, engagement and performance), so that further interventions can be identified to support the wellbeing of the participants.

The talk will outline the statistical data science methods used to overcome the substantial computational challenges associated with the data wrangling and modelling of the risk factors for such a large dataset.

3 Abstracts of posters

Results on Ask Zeta Functions

Sultan Alzahrani
Supervisor: Tobias Rossmann

This poster contributes to certain generating functions known as *ask zeta functions* $\mathsf{Z}^{\mathbf{ask}}_M(T)$ for modules M of matrices over compact discrete valuation rings [2]. The coefficients of the generating functions $\mathsf{Z}^{\mathbf{ask}}_M(T)$ are obtained from the average sizes of the kernels of the elements of M over finite quotients of the base ring. Let k be a number field with ring of integers $\mathcal{R}$. Let $\mathcal{V}_k$ be the set of non-Archimedean places of k. For $v \in \mathcal{V}_k$, let k_v be the v-adic completion and let $\mathcal{R}_v$ be its valuation ring. We obtained the following results:

- We give an explicit formula for the local and global ask zeta functions of modules generated by a single matrix.
- Let $A \in \mathrm{M}_n(k)$. For almost all places $v \in \mathcal{V}_k$, we write a general formula for the local ask zeta functions of modules generated by the identity matrix I_n and A over $\mathcal{R}_v$.
- We provide a way of computing the local ask zeta functions for modules of anti-symmetric matrices using the set of all principal Pfaffians.
- We produce an explicit formula for the local ask functions of modules of anti-symmetric matrices with smooth Pfaffians hypersurfaces.
- We define equivalences of relation modules [1] and introduce reductions of partial colorings of one color.

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Optimisation of cancer status prediction pipelines using bio-inspired computing *

Mariel Barbachan e Silva
Supervisor: Pilib Ó Broin

Cancer is one of the leading causes of death globally, and early detection is a fundamental factor in improving patient outcomes [1]. The advent of high-throughput genetic profiling techniques in the last few decades has led to an explosion of genetic data related to cancer. Machine learning methods, and classification algorithms in particular, have been used to find underlying patterns in cancer data and make diagnostic predictions [2]. The addition of feature selection to classification pipelines can lead to improvements in predictive capabilities, since the removal of non-important features benefits the construction of classification models [3]. We developed a classification pipeline for cancer status prediction composed of a feature selection step with SelectKBest and an ensemble classifier system with five popular supervised learning algorithms. We used three bio-inspired optimisation techniques to select the optimal sets of hyperparameters for the classification pipeline and compared these approaches on three cancer microarray datasets. The results indicate that the optimised pipelines have better predictive performance in all but one of the experiments compared to the ensemble alone.

Supported by College of Science fellowship from NUI Galway.

* This work was accepted for oral presentation at the 2021 IEEE Congress on Evolutionary Computation.

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data. 2017 International Conference on Computational Intelligence in Data Science (ICCIDS), 2017.

Controlling for background genetic effects using polygenic scores improves the power of genome-wide association studies

Declan Bennett
Supervisor: Prof. Cathal Seoighe

Linear mixed models are routinely used in genome wide association studies (GWAS) to identify genomic variants that are statistically associated with a phenotype of interest. As each of the genetic variants are tested one at a time, the variants that are not in linkage disequilibrium can contribute to the variation in the phenotype (background genetic effects). Background genetic effects can be modelled explicitly through a random effect with covariance proportional to the kinship matrix, although these methods have a significant computational time and memory cost. Efficient GWAS methods that use a sparse kinship matrix, requiring a fraction of the memory resources and computational time, have been developed but have a reduced power over the state-of-the-art methods due to the sparsity in the kinship matrix. We show that by incorporating phenotype prediction methods as fixed effects in GWAS we can account for background genetic effects. By simulation and application to real data we show that our method can, on average, recover more causal genetic variants at a significantly reduced computational cost. This increase in power to detect trait-associated variants also translates into an increase in the accuracy with which the resulting polygenic score predicts the phenotype from genotype data. Our results suggest that advances in methods for phenotype prediction can be exploited to improve the control of background genetic effects, leading to more accurate GWAS results and further improvements in phenotype prediction.

This research has been conducted using the UK Biobank Resource under Application Number 23739. This publication has emanated from research conducted with the financial support of Science Foundation Ireland under Grant number 16/IA/4612

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Bayesian concurrent functional regression for sensor data

Beatrice Charamba
Supervisor: Andrew Simpkin , John Newell

Introduction

Functional data analysis (FDA) methods have recently been developed to analyse several variables measured repeatedly and concurrently over a domain such as time in a cohort of individuals. However, many FDA methods require data to be measured regularly, with data being collected at the same fixed times for all individuals. Often, with studies in humans, there tend to be missing data. Some studies focus on sparse but regular data and some focus on dense but irregular data. Of those who focus on both sparse and irregular data, only a few have readily available software to implement their methods and they use only complete case data for modelling, and hence some information is lost. In this study, we developed a Bayesian model for function-on-function regression in the situation of sparse and irregular data which uses all the data for modelling and easily obtain inferences.

Methods

A simulation study was performed to compare the Bayesian model with other methods available in software to determine which performs best when there are sparse and irregular data. Four functions for the parameter were considered (linear, exponential, fifth order polynomial and sinusoidal). Missingness was induced in four ways, 10%, 20% and 40% missing at random as well as missing chunk of data. Three sample sizes were considered, 50,100 and 250. Number of observations per individual considered were, 50,100, 300 and 1000. Bayesian model was then

applied to concurrently measured glucose (every 5 minutes for 1 week) and electrocardiogram (ECG) data (every 10 minutes for 1 week) in a cohort of n = 17 type 1 diabetics. All models were fitted using R v 3.5.

Results

The Bayesian model is competitive with other models particularly in complex (fifth order polynomial and sinusoidal functions) and irregular data. Its performance drops in the linear and exponential functions. It was found the Bayesian model is robust to missingness compared to other models especially.

Conclusion

For irregular sensor data with missingness, the Bayesian model is a good model hence we recommend the use of Bayesian functional regression model for such data.

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Prediction of Allele Specific Expression for Tumor Suppressor Genes

Siobhán Cleary
Supervisor: Cathal Seoighe

Allele-specific expression (ASE) arises when one allele of a heterozygous SNP results in an imbalance in the expression of the gene in an individual. ASE analysis involves data from both RNA and DNA sequencing experiments for a single sample. Due to the high costs and limited amounts of specimen taken from biopsies it is not always possible to have data from both RNA and DNA sources. Additionally ASE requires higher read counts than the more common expression analysis for which RNA-Seq data is generally derived. Therefore, we aim to predict ASE using genotype data only.

ASE is prevalent in cancer samples and is one of the major classes of RNA alteration [1]. We propose that ASE levels in tumor suppressor genes (TSG) is a potential risk factor for the development of cancer and aim to generate a score for the extent of TSG ASE within an individual and to use this score to assess the association of ASE with cancer risk.

In this poster we present our results using ASE data from the Genotype-Tissue Expression (GTEx) project, generated by [2] to predict ASE. We identify variants that show imbalance in TSG in a set of samples and use these variants to generate weights which can be used to score a new set of samples to predict the extent of TSG ASE. We then assess the ability of the scoring method to predict ASE.

Supported by Science Foundation Ireland.

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nf-core/circrna: a nextflow workflow for the quantification, microRNA target prediction and differential expression analysis of circular RNAs in RNASeq data

Barry Digby
Supervisor(s): Pilib Ó Broin, Stephen Finn (TCD/SJH)

Circular RNAs (circRNAs) are a class of non-coding RNA (ncRNA) that have gained attention due to their unique covalently closed loop structure, tissue-specific expression, and abundant expression in saliva, blood, plasma and exosomes [1, 2]. Furthermore, highly expressed circRNAs have the ability to titrate microRNAs (miRNAs) via miRNA response elements within their mature spliced sequence [3], making the study of circRNAs within the competing endogenous RNA (ceRNA) network at a systems level highly pertinent in both the context of diagnostic and prognostic biomarkers in a clinical setting and as novel therapeutic drug targets.

To elucidate these mechanisms, we present *nf-core/circrna*, a multi-functional, automated high-throughput pipeline implemented in Nextflow [4] that allows users to fully characterise circRNAs in RNA-Seq datasets via 3 analysis modules; (i) circRNA quantification, robust filtering and annotation (ii) miRNA target prediction of the mature spliced sequence and (iii) differential expression analysis between pathological conditions complete with statistical results, diagnostic and expression plots. *nf-core/circrna* has been developed within the nf-core framework [5], ensuring robust portability across compute environments via containerisation, deployment on cluster/cloud based infrastructures, comprehensive documentation and maintenance support. Source code, documentation and installation instructions are freely available at https://github.com/nf-core/circrna and https://nf-co.re/circrna.

Supported by Science Foundation Ireland under grant number 18/CRT/6214

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Using single-cell transcriptomics to characterise the bone marrow micro-environment in health and leukemia

Sarah Ennis
Supervisor: Dr Eva Szegezdi, Dr Pilib Ó Broin

Acute myeloid leukemia (AML) is an aggressive blood cancer which causes an accumulation of myeloid precursor cells in the bone marrow. Drug resistance is common among AML patients and is thought to be partly driven by the protective micro-environment in which the cells reside. Recent studies using single-cell technologies have provided valuable insights into the behaviour of the bone marrow niche in individual AML patients and also demonstrated the high level of both inter- and intra-patient heterogeneity present among AML cells. However, due to economic and experimental hurdles, the throughput of these studies has remained restricted to very few patients and so the ability to identify any unifying mechanisms of AML progression from them is limited. Here, we have performed single-cell RNA sequencing of bone

marrow aspirates from 10 AML patients, at different stages of disease progression (diagnosis, post-treatment and relapse) and integrated the data with several published single-cell studies of both healthy and AML bone marrow. The combined dataset consists of over 250,000 cells from more than 60 donors. Using this dataset, we first constructed an atlas of healthy cells to establish a baseline reference of the behaviour of cells in the bone marrow micro-environment. We then added the AML data to this atlas and looked for changes in cell type composition, gene expression and cell signalling that occur in the bone marrow during the establishment and progression of AML. This analysis further highlighted the amount of heterogeneity among AML patients but due to the large size of this dataset, we were also able to discover certain disease features that are common across most AML patients and could represent potential therapeutic targets which warrant further investigation.

Polygenic Scoring vs. XGBoost Machine Learning method for predicting Intelligence based on genotype data

Laura Fahey
Supervisors: Dr Pilib Ó Broin and Dr Derek Morris

Recent genome-wide association studies (GWAS) have revealed that the genetic component of many complex phenotypes is often based on the cumulative contribution of a large number of small effects – this is referred to as a polygenic model. A polygenic score (PGS) is a linear combination of effects from a GWAS that represents and can be used to predict genetic predisposition to the phenotype in question. A key limitation of the PGS method is that it assumes additive and independent SNP effects, when it is known that epistasis (gene interactions) can contribute to complex traits. Machine learning methods can potentially overcome this limitation by virtue of their ability to capture non-linear interactions in high dimensional data. Intelligence is a complex trait for which PGS prediction currently explains up to 5.2% of the variance, a relatively small proportion of the heritability estimate of 50% obtained from twin studies. This project aims to investigate the performance of gradient boosting, a machine learning technique based on an ensemble of weak prediction models, in predicting intelligence from genotype data when compared with the standard polygenic score (PGS) approach.

Supported by Irish Research Council

Genus g Partition Functions of Vertex Operator Algebras

Michael Flattery
Supervisor: Michael Tuite

This poster presents the partition functions of Vertex Operator Algebras (VOAs) on a genus g Riemann surface [1] as part of an investigation into a conjecture of Friedan and Shenker [2] that a VOA is determined by its partition functions of all genera. This genus g Riemann surface is constructed by sewing handles on a Riemann sphere through Schottky uniformisation. We show this conjecture has been verified for the class of lattice VOAs and introduce how techniques using degree l Casimir operators of the Lie Algebra generated by the states of conformal weight 1 and an alternative approach to constructing a genus g Riemann surface are being used in dealing with a much broader class of VOAs [3].

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Modelling evolution of polymer molecular weight distribution during degradation

Aoife Hill
Supervisors: William Ronan, Michel Destrade

Further development of bioresorbable devices for use in clinical applications, where they can reduce long term risks, has been hindered by the many underlying complex degradation mechanisms that bioresorbable polymers exhibit and the resulting difficulty this causes in designing suitable devices. Motivated by existing degradation models [1, 2], we present a kinetic scission model to predict how the molecular weight distribution evolves as a function of degradation time for bioresorbable polymers. Here, a refined kinetic model has been developed to capture the autocatalytic effect of carboxylic acids created via chain scissions and our framework accounts for reduction in molecular weight via the cleavage of monomers from chain ends and from scissions in the middle of the polymer chain. These developments allow for a more complete representation of the molecular weight distribution during degradation. The results obtained are quantitatively compared to and calibrated with existing experimental data for PLGA films [3].

Supported by the Irish Research Council, GOIPG/2018/2697.

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Layer-adapted meshes generated using mesh PDEs

Name Róisín Hill
Supervisor: Niall Madden

We consider the numerical solution, by finite element methods, of singularly-perturbed differential equations (SPDEs) whose solutions exhibit boundary layers.

Our interest lies in developing parameter-robust methods, where the quality of the solution is independent of the value of the perturbation parameter. One way of achieving this is to use layer resolving methods based on meshes that concentrate their mesh points in regions of large variations in the solution.

We investigate the use of Mesh PDEs (MPDEs), as first presented in [4], to generate layer resolving meshes that yield parameter robust solutions to SPDEs. Specifically, we present MPDEs whose solutions, in the 1D case, yield the celebrated graded "Bakhvalov" meshes [2].

The true value of the proposed approach comes to the fore when we investigate 2D problems. Whereas the classical Bakhvalov mesh is restricted to generating tensor product grids, the use of MPDEs allows us to generate non-tensor product grids that are still highly anisotropic and layer-adapted grids, and yield robust solutions.

As the MPDEs are non-linear problems, we use a fixed-point iterative method to solve them numerically. We present an approach involving alternating between h- and r-refinement which is highly efficient, especially for larger meshes and small values of the perturbation parameter.

Results and source code are available as: Generating layer-adapted meshes using mesh partial differential equations; `https://osf.io/dpexh/`(to appear on Numer. Math. Theor. Meth. Appl.) [3].

Supported by the Irish Research Council, GOIPG/2017/463.

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Predicting immunogenicity using mutational signatures and MHC-I genotype

Noor Kherreh
Supervisor: Cathal Seoighe

The presentation of intracellular antigens on the cell surface by Major Histocompatibility Complex class-I (MHC-I) molecules is one of the major determinants for CD8+ T-cell activation. The binding affinity of the MHC-I molecule for peptides depends predominantly on three genes encoded at the human leukocyte antigen (HLA) locus on chromosome 6: HLA-A, HLA-B, and HLA-C. Recent research has shown that patient MHC-I genotype influences immunotherapy responses. For example, the B44 HLA supertype is associated with a better response in Melanoma. Non-Small Lung Cancer (NSLC) has a similar somatic mutation burden and immunotherapy response to melanoma; however, the B44 supertype has not been found to influence immunotherapy response in NSLC. This has been attributed to underlying differences in mutational processes active in Melanoma compared to NSLC. For example, transition mutations, mainly C>T, caused by ultraviolet light exposure in melanoma cancer, tend to result in neoantigens that are more strongly bound by MHC molecules of the HLA B44 supertype than transversion mutations, particularly C>A associated with the tobacco smoking signature often found in NSLC.

To generalize these findings, here we set out to perform an exhaustive characterization of the predicted immunogenicity of mutations arising from all cancer mutation signatures for all of the major HLA supertypes. We observed that mutations resulting from some mutation signatures were far more likely to be presented by certain HLA alleles than mutations from other signatures. The average number of mutations that were predicted to be immunogenic in a cancer type could be predicted with high accuracy ($R^2 = 0.83$) from the mean activity of the mutation signatures in that cancer. Immunoediting, which refers to the depletion of immunogenic mutations during cancer development in a process of evasion of the immune response, has been proposed to shape the somatic mutations observed in cancer. However, the fact that the immunogenicity of the observed somatic mutations in cancer can be predicted from the mutation profiles alone leaves little room for a contribution from immunoediting. We plan to use the immunogenicity predicted from mutational signatures as basis to place an upper limit on the impact of immunoediting on the somatic mutations observed in cancer.

Computing invariants of knotted manifolds

Kelvin Killeen
Supervisor: Graham Ellis

In this poster, we show how the classical notions of homology with local coefficients, covering space, tubular neighbourhood and spinning can be encoded on a computer and used to calculate ambient isotopy invariants of continuous embeddings $N \hookrightarrow M$ of topological manifolds. More specifically, we are concerned with the case of codimension-2 embeddings of knots into $\mathbb{R}^3$ and knotted surfaces into $\mathbb{R}^4$. To this end, we have implemented algorithms for endowing these manifolds with efficient regular CW-structure. In the case of knotted surfaces, we have implemented Satoh's tube map [1] which associates ribbon torus-knots to virtual knot diagrams.

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Assessing the Role of Genomics Data in Stratifying Patients within Predictive Models for Breast Cancer Survival Outcome

Lydia King
Supervisor: Dr. Emma Holian, Dr. Simone Coughlan and Dr. Róisín Dwyer

Breast cancer is one of the most common malignancies affecting women worldwide and is the leading cause of cancer-related death among this group. Breast cancer diagnosis, classification and treatment generally follows an integrative approach whereby both clinical features and tissue-based biomarkers are used. This project focuses on assessing whether biomarkers derived from genomics data, in particular gene expression and copy number alteration (CNA) signatures, improve predictive models of overall survival, disease-specific survival and response to therapy, for breast cancer patients in the clinical setting. It is widely accepted that breast cancer is largely dominated by amplifications, deletions and chromosomal rearrangements and a growing body of evidence suggests that the incorporation of the genomic landscape of the tumour into treatment decisions is extremely beneficial to the patient.

To investigate the role of genomic instability (GI) in breast cancer survival, we first define novel CNA metrics to measure GI in the METABRIC cohort requiring estimating the distribution of those metrics with missing value presentation. A further challenge is in incorporating the CNA metrics into predictive models as this requires consideration to modelling the effect of the upper tail of those distributions, i.e. those with high genome instability rather than central tendency. Modelling survival with recursive partitioning survival trees enables us to investigate possible interactions between clinical variables and the derived CNA metrics, and the relationship with established molecular-based classification methods such as PAM50 intrinsic subtypes and the more recently defined Integrative Clusters. Further to this, focus on the location of the CNA burden i.e. the chromosome arms and alteration status across genes at adjacent locations on a chromosome, indicate that for a subset of patients higher levels of deletion burden on chromosome arms 3p and 18q are associated with worse disease-specific survival.

Supported by Science Foundation Ireland and the National Breast Cancer Research Institute (NBCRI) under Grant number 18/CRT/6214.

LncRNAs associated immunogenicity scoring as prognostic biomarker of LUAD

Sumaira Malik
Supervisor: Aaron Golden

Lung cancer is one of the most malignant types of cancers. Lung Adenocarcinoma (LUAD) is one of the most frequent subtypes of lung cancer. The use of immune checkpoint inhibitor (ICI) therapy has been a paramount achievement of the last decade, and its use has been approved for different types of cancers, including non small cell lung cancer (NSCLC). Despite the remarkable success, response to ICI therapy is inconsistent among patients. The five-year survival rate of LUAD is less than 15%; however, stratifying patients using prognostic biomarkers and finding their association with previously described predictors of ICI efficacy might help improving survival rates.

The main focus of this study is to identify lncRNAs as a source of MHC-I binders and immunogenicity scoring based on such lncRNAs as a prognostic biomarker in LUAD. MHC-I proteins are cell-surface proteins that present antigens at tumor surfaces to regulate T-cells mediated tumor elimination. Recent studies have highlighted the importance of peptides derived from non-coding RNAs. Laumont et al. have shown that non-coding RNA antigens elicited T- cell responses improving overall survival in vivo mouse cancer models. Among non-coding RNAs, lncRNAs have short open reading frames (sORFs) that cannot produce functional proteins. However, they can produce short tumor associated peptides. These peptides can bind to MHC-I genes. We set to explore if

immunogenicity scored based on differentially expressed translatable lncRNAs are associated with survival outcomes in LUAD. We define immunogenicity scores for each patient as total number of lncRNA antigens it can present. We hypothesized that patients with high immunogenic scores are likely to be associated with better survival. We explored TCGA LUAD dataset to identify differentially expressed translatable lncRNAs. The sorfs from these lncRNAs were then used to assign immunogenicity scores to each TCGA case. Patients were then assigned to ranked quartiles based on segmentation of immunogenicity scores. These quartiles were then associated with survival analysis using the log-rank test and Kaplan Meier estimation.

The results suggested significant difference in survival probabilites of patients in q4 (group with high immunogenic scores) versus q1 (low immunogenic scores). KM survival curves for quartiles indicated that patients in q4 (high scores) had better survival than patients in q1 (low scores). The difference in survival curves between q4 and q1 is significant with a p-value < 0.05. We also demonstrated that patients in the worse survival group had a higher median 12-chemokine gene expression signature (12-CK GES) than patients in q1. 12-CK GES has been shown as a biomarker of ICI efficacy by previous studies. The results suggest that lncRNA associated immunogenicity scoring act as a prognostic biomarker and might help stratify patients that can benefit from ICI therapy.

Correlating Oncogenic Mutations and Histopathological Features in Melanoma using Deep Learning

Pierre Murchan

Supervisors: Dr. Stephen Finn & Dr. Pilib Ó Broin

In Irish melanoma cohorts, the BRAF mutation rate is half of that observed in international studies at approximately 25% [1]. The next most frequently observed driver mutations are found in the NRAS gene followed by NF1, however the rate of NRAS mutation in the Irish population is consistent with international figures of approximately 20% and NF1 is not routinely profiled. This means that there may be a missing molecular component in Irish clinical melanoma cases. Long turnaround times, high costs, and limited amount of tumour material available for molecular testing prevent the mass sequencing of Irish melanoma cases to uncover this un/under-recognised molecular component. Meanwhile, hematoxylin and eosin (H&E) stained histopathology slides are routinely collected for cancer cases. Deep learning has been shown to be capable of predicting mutated genes from digitised histopathology images in lung adenocarcinoma and hepatocellular carcinoma [2, 3]. The aim of this study is to predict mutated genes from digitised melanoma histopathology slides using deep leanrning, such that the unrecognised molecular subtype in Irish melanoma cases can be identified.

A deep learning model (Inception v3) was trained on H&E stained fresh-frozen histopathology slides of the TCGA-SKCM dataset in order to predict the mutation status of 10 commonly mutated genes in melanoma. Future work will focus on training a deep learning model on FFPE histopathology slides before generalising the model to a dataset of Irish melanoma cases.

Per-tile AUCs ranged from 0.33 (MAP2K1) to 0.66 (ARID2) on the validation dataset. Per-slide AUCs were determined by averaging the probability of each class across all tiles in a slide and ranged from to 0.09 (MAP2K1) to 0.75 (NF1). Preliminary results suggest that deep learning may have value in predicting the mutation status of selected genes from H&E stained histopathology slides in melanoma.

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Feature Extraction in Motion Tracking Data In Elite Soccer

Pouyan Nejadi
Supervisor: Prof. John Newell

Efforts at player motion tracking have traditionally involved a range of data collection techniques from live observation to post-event video analysis where player movement patterns are manually recorded and categorised to determine performance effectiveness. The availability of motion tracking data in elite sports has opened up new and exciting areas of research in sports and data science. For example, in an elite soccer match data are collected on each player's movement using camera equipment installed around the stadium which captures their movement (x,y and z coordinates) 25 times per second. Such granular data are needed to quantify and understand an athlete's quick and agile movements, involving many unpredictable changes in direction and frequent collisions with other players. The quantitative analysis of team and player activity is an important aspect of team tactics and the coaching process and in player welfare, rehabilitation and recruitment.

This poster presents two methods of how such data can be utilised in elite soccer. In the first approach, clustering methods are presented to identify regions of interest for a player and a method to identify how a player transitions between regions. The second approach describes methods for feature extraction from motion tracking data which are useful covariates when modelling player movement patterns.

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Observations of the pulsar PSR B0540-69 using the BVIT Detector on the South African Large Telescope

Deirdre Ní Chonchubhair
Supervisor: Dr Aaron Golden

Located in the nearby Large Magellanic Cloud [1], PSR B0540-69 is the second brightest optical pulsar detected to date with a period of 50 milliseconds. Due to its youth and position within its supernova remnant, PSR B0540-69 is often referred to as the Crab pulsar's twin [2]. Despite this similarity, it has not been as extensively studied as the latter, partly due to PSR B0540-69 being about 100 times fainter than the Crab pulsar, and its location in the Southern sky. The largest of optical telescopes combined with the most sensitive high-speed detectors are needed to observe such faint objects. The Berkeley Visible Imaging Tube (BVIT) [3] is a photon counting detector currently mounted on the 11m South African Large Telescope (SALT), the largest optical telescope in the Southern hemisphere. Using BVIT and SALT, PSR B0540-69 was observed over four nights in December 2013 - the first observations of an optical pulsar with the BVIT/SALT combination. A bespoke data pipeline was developed to analyse this data and using signal processing algorithms we detected the pulsar rotating with a frequency of 19.7105 ± 0.0005 Hz, yielding a period of 50.7 ms – consistent with the expected PSR B0540-69 period [4] – and recovered the $\sim$ double-peaked light curve observed in optical, γ and X-rays, offering insights into the pulsar's emission mechanisms. Prior to this work, the observational magnitude limit of BVIT/SALT was estimated by the BVIT group to be about 20th magnitude in V-band. The recovery of a strong signal from PSR B0540-69 ($\sim$ ten times fainter than this estimated limit) demonstrates the potential of time-resolved imaging using this observing configuration.

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Deriving Intermediate Phenotypes for Bipolar Disorder Using a Convolutional Neural Network

Shane O'Connell
Supervisor: Pilib Ó Broin

Bipolar disorder (BD) is a chronic mood disorder characterized by manic, hypomanic, and depressive episodes, often interspersed by periods of euthymia (normal mood) [1]. A population prevalence of 2% worldwide has made it the subject of intense research, with several neuroanatomical studies highlighting regions of the brain with differential morphology in BD patients versus controls [2, 5]. The biological underpinnings of BD have also been investigated through genome wide association studies (GWAS), which have, to date, detected several single nucleotide polymophisms (SNPs) significantly associated with the disorder [3, 4]. However, the precise biological mechanism of lead SNPs can be difficult to interpret, and GWAS of BD require large sample sizes, possibly owing to the heterogeneity of the condition. In order to address these association problems, we propose the use of 'endophenotypes' - intermediate phenotypes associated with the main phenotype - derived from T1-weighted magnetic resonance imaging (MRI) data. Regions of interest derived from neuroanatomical studies to date include the amygdala, ventricles, and hippocampus, but these studies have relied on predefined structural segmentation atlases [5]. We therefore propose endophenotypes derived from convolutional neural networks (CNNs), a family of flexible deep learning models suited to image analysis and computer vision, which will consider the entirety of an image during training [6]. We developed a custom built CNN with 5 convolutional layers and 5 fully connected layers that achieved competitive discriminative performance between cases and controls (acc=64%,auc=0.63, n=300,case%=48) and used gradient based class activation mapping (Grad-CAM) to highlight the regions that contributed the most to classification [7]. The patients were all euthymic at the time of MRI acquisition, meaning results were not state specific. To ensure findings were robust, we examined concordance of important regions across differing preprocessing pipelines. Finally, we applied the same approach to semantically segmented brain data from the same sample to compare implicated regions. Our findings have the potential to inform future GWAS of BD and detect SNPs with an effect on BD through a deep learning derived endophenotype.

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A New Perspective to Symmetric Group Representations and Specht Modules

Koushik Paul

Supervisor: Prof. Götz Pfeiffer

We call a *Young tableau* of shape λ to be standard if the labels inside the boxes $\{1,2,\ldots,n\}$ are arranged in such way that every row and every column is increasing. Let n be any natural number. To study symmetric group representations we need to study about Young tableaux as they give a nice combinatorial understanding of the topic.

In the existing literature [1] we can find that for a tableau t, the associated polytabloid is e_t. For any partition $\lambda \vdash n$, the correspondng *Specht module*, S^λ is the submodule of M^λ (permutation module corresponding to λ) spanned by the polytabloids e_t, where t is of shape λ. Here we also get a nice proof that the set $\{e_t \mid t \text{ is a standard } \lambda-\text{tableau }\}$ creates a basis for S^λ.

Recently in [2] a new approach towards Specht modules has been noticed using the notions of so called *Specht matrices*. This is further more computational and combinatorial understanding of Specht modules than what was known from the previous literatures.

This work started with the primary investigation to find out the relationships between the existing theory and the novel concepts using computational tools [3]. Thereafter it has reached at a stage where it can be said that the columns of Specht matrix in which the standard tableaux lie do create a basis of S^λ. Hence e_t is just a representation of the columns of Specht matrix concerned with a partition λ. Not just that but it also tells us about the shape of these matrices which are rather fascinating.

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Parity Binomial Edge Ideals with Pure Resolutions

Peter Phelan

Supervisor: Emil Sköldberg

The parity binomial edge ideal of a simple undirected graph G was introduced in [1] by Kahle, Sarmiento and Windisch.

Definition. The parity binomial edge ideal of a graph G is given by

$$J_G = (x_i x_j - y_i y_j \mid \{i,j\} \in E(G)) \subseteq \mathbb{K}[x_i, y_i \mid i \in V(G)]$$

We are interested in studying parity binomial edge ideals with pure resolutions. These resolutions have been the subject of serious interest in recent years, often described as the "building blocks" of Betti diagrams. A Betti diagram is a table of Betti numbers, which are vitally important homological invariants in commutative algebra. Conjectures posed by Boij and Söderberg, later proven by Eisenbud and Schreyer, demonstrate how pure resolutions can be used to examine the range of admissible Betti diagrams. An excellent review of this topic can be found in [2].

In this poster, we outline some recent work [3] in characterizing all graphs whose parity binomial edge ideals have pure resolutions. In particular, we show that the minimal free resolution

of a parity binomial edge ideal is pure if and only if the corresponding graph is a complete bipartite graph, or a disjoint union of paths and odd cycles.

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Dimension Witnesses in Prepare and Measure Scenarios

Billy Ray
Supervisor: Dr. Mark Howard

Certifying the dimension of classical and quantum systems in a "black-box" scenario, that is, a scenario where no assumptions are made regarding the functioning of the devices used in the experimental setup, is a routine task in quantum information science. This task boils down to determining the dimension of a system by investigating experimental statistics alone.

Prepare and measure (PM) scenarios have lent themselves well to the above problem. A PM scenario consists of two spatially separated devices: a state preparator and a measurement device, each with a fixed number of settings. The experimental statistics are given by the conditional probabilities that a certain outcome was produced by the measurement device, given that a certain preparation-measurement combination was chosen. These probabilities give rise to the notion of a *dimension witness*, an inequality which will only be satisfied by systems of a certain dimension.

Due to the computational cost associated with deriving dimension witnesses, researchers have limited themselves to PM scenarios where the measurement device only produces binary outcomes. The aim of this project is to derive a dimension witness for three-dimensional quantum systems, where the measurement device has *three outcomes*. This work could serve as the foundation for deriving a generic dimension witness which can be applied to all PM scenarios involving three-outcome measurements.

This poster presents the following: the quantum theory needed to understand the tasks outlined above, a general illustration of PM scenarios and their intimate connection to convex geometry, and the role linear programming plays in computing witnesses which have high computational costs associated with them.

Supported by The College of Science and Engineering Postgraduate Research Scholarship Scheme, NUIG.

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2-uniform covering groups of elementary abelian 2-groups

Dana Saleh
Supervisor: Rachel Quinlan

We refer to a Schur covering group of an elementary abelian 2-group as *uniform* if it has a generating set consisting of elements all having the same square, and *2-uniform* if it is not uniform and has a generating set consisting of elements having just two distnct squares. It was shown in [1] that isomorphism types of uniform covering groups of $C_2^{(n)}$ correspond exactly to isomorphism types of simple undirected graphs on n vertices. In the 2-uniform case, the correpsondence is again with graphs on n vertices, but with the additional ingredient of 2-colourings on both the vertex and edge set. The correpsondence is not bijective, as it is possible for a single group to be represented by multiple non-isomorphic 2-coloured graphs. We give an account of how a presentation for a covering group may be encoded as a graph, and give a full description for the cases $n = 3$ and $n = 4$.

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Nash Equilibria in certain two-choice multi-player games played on the ladder graph

Victoria Sánchez Muñoz
Supervisor: Michael Mc Gettrick

One of the branches of Game Theory deals with the so-called **Graphical Games** [1]. To define a graphical game, a certain graph $\mathcal{G}$ and a game are needed. The vertices of the graph $\mathcal{G}$ represent players and each player will play the defined game with their (direct) neighbours, that is, the players connected to them by an edge. The study of the possible solutions, in particular, the **Nash Equilibrium (NE**) solutions [2], in that network of players has several applications in other fields: for instance, see [3, 4, 5, 6] for connections to Biology, Economics, Sociology and Computer Science, respectively.

In our research, the graph/s are a ladder and a circular ladder. The underlying game is defined for two players, who can pick between two strategies: a or b. The game is defined such that it has two NE: when the players choose opposite strategies (anti-coordination game). Our goal was to find how many NE there are when that same game is played pair-wise on the ladder and the circular ladder for a generic number of players $2n$, with $n = 1, 2, 3, ...$. As opposed to the algorithmic approach usually employed to obtain the solutions for graphical games, we found an analytical expression to count the number of NE for both graphs. Surprisingly enough, the base of the exponential growth found for the number of NE is the ubiquitous *golden ratio* $\varphi = (1+\sqrt{5})/2 = 1.618....$

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Modelling and Predicting Drug (and Polypharmacy) Side Effects with Machine Learning Methods via identifying and integrating Heterogeneous Genomics Data

Yezhao Zhong
Supervisor: Dr. Haixuan Yang, Prof. Cathal Seoighe

Polypharmacy is a type of drug combinational therapy providing a promising strategy in the treatment of complex diseases. Complex biological processes are involved and therefore, it can improve the performance, but at the same time, increase the risk of having adverse drug reactions (ADRs). However, ADRs are hard to detect because it is highly costly and time-consuming. Therefore, computational network-based methodologies are developed to predict the polypharmacy side-effect.

Heterogeneous datasets were used in the development of the method. LINCS L1000 [1] that contains 8,347 genes, 30,970 small molecules, and 4,184,199 gene - small molecule perturbation associations datasets are adopted. The association of gene and small molecule perturbation is represented by increased or decreased expression, which can innovatively adopt the gene expression data into the network-based prediction of polypharmacy

ADRs. Other features are extracted from various data such as chemical structures or protein targets from PubChem. And drug pairs side-effects from TWOSIDES can be the label for predicting ADRs. Graph Regularized Nonnegative Matrix Factorization is utilized to solve the network [2]. A network was constructed by the association of gene and small molecule, coding 1 as increased expression gene and -1 as decrease expression gene. To apply this network into GRNMF, data matrix A is set as the drug (or drug pairs)-side effect association data. One of the important issues in this model is the missing value in the network, which means networks are incomplete when they are extracted from different datasets e.g., The number of the intersection of drug pairs between L1000 and TWOSIDES is only 34,549 which is far less than the number drug pairs in L1000 [3]. Therefore, we can improve the performance by predicting the missing part of the network by other network features, and further develop as a strategy of ADRs prediction for new drugs.

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4 Abstracts of PhD theses

Groupoids and computational topology

Nisreen Alokbi
Supervisor: Graham Ellis

This thesis contributes to the computational theory of finitely presented groupoids. It develops, implements and illustrates data types and algorithms aimed at pure and applied topology. In particular, the thesis designs and implements data types for: • free groupoids, • elements in free groupoids, • finitely presented (fp) groupoids, • homomorphisms of fp groupoids. The thesis designs and implements algorithms for: • composition of elements in a free groupoid, • path components of a fp groupoid, • a finite presentation for the vertex group of a fp groupoid, • a finite presentation for finite index subgroups of an fp group, • pushouts of fp groupoids, • a finite presentation for the fundamental groupoid of a finite, regular CW- complex, • the homomorphism of fundamental fp groupoids induced by an inclusion of finite regular CW-complexes, • the low-dimensional cup product on the cohomology of a finite regular CW-complexes, • a re-implementation of the Mapper algorithm for obtaining examples of finite simplicial complexes derived from experimental data, • a re-implementation of an approximation for the dominant eigenvectors of a floating point symmetric matrix (for use with the Mapper algorithm). The thesis contains illustrations of the above data types and algorithms such as: • the computation of a finite presentation of the fundamental group of a finite regular CW-complex based on the groupoid version of the van-Kampen the- orem. This allows for parallel computation of low-dimensional cup products, • the fundamental groupoid (and group) of simplicial complexes arising, via Mapper, from gait analysis data, • the fundamental groupoid (and group) of simplicial complexes arising from time-series data.

Non-cut points in Hausdorff continua

Daron Anderson
Supervisor: Aisling McCluskey

The worlds of metric and non-metric continuous curves show disparity with regards to the existence and non-existence of special types of non cut points. The thesis focuses on shore points, non block points and strong non cut points.

Characterising bases of pure difference ideals

Isaac Z. Burke
Supervisor: Emil Sköldberg

In this thesis, we study the basis sets of pure difference ideals, that is, ideals that are generated by differences of monic monomials. We examine the action of the hyperoctahedral group on the defining ideal of the Segre variety in the multi-dimensional case and present some striking computational results. We characterise the universal Gröbner basis for the 4-dimensional binary case of this ideal. Separately, in order to create a classification of non-toric pure difference ideals, we introduce and study the concept of a Gröbner-reversible pure difference ideal. We also outline a method for enumerating the Graver bases of some pure difference ideals that are not lattice ideals. Binomial edge ideals are binomial ideals that arise naturally from simple graphs. We show that the universal Gröbner basis and the Graver basis of a binomial edge ideal coincide. We provide a description for this basis set in terms of certain paths in the underlying graph. We conjecture a similar result for a parity binomial edge ideal and prove this conjecture for the case when the underlying graph is the complete graph. The maximum likelihood degree (ML degree) of an algebraic variety V is a measure of the complexity of the problem of maximum likelihood estimation for a statistical model corresponding to V. We demonstrate that the ML degree of a scaled Segre variety Vc depends on certain algebraic and geometric properties of the scaling parameter c. We give a sufficient condition for a scaled Segre variety Vc to have ML degree one and describe how the ML degree drops when c has a particular multiplicative structure. We also put forward a number

of conjectures and give a closed form expression for the solutions to the likelihood equations for the simplest non-trivial case.

Wrinkles and waves in soft dielectric plates

Hannah Conroy Broderick
Supervisor: Michel Destrade

This article-based thesis comprises a collection of three articles, each of which constitutes a separate chapter, written and formatted in pre-print manuscript form. The general aim of the thesis is to model instabilities and waves in soft dielectric elastomer plates, with a particular focus on wrinkle formation and wave propagation modes. Soft dielectric materials are smart materials that deform in the presence of an electric field. They have potential promising applications in devices such as artificial muscles and soft robotics, where there is great demand for materials that can undergo repeated large deformations. In principle, large deformations can be obtained by exploiting the so-called snap-through instability. However, this phenomenon is difficult to achieve and control in practice, as the material often fails due to electric breakdown, or due to wrinkles appearing on the surface of the material. Here we study in turn the stability of voltage and charge-controlled soft dielectric plates. We investigate Hessian and geometric instability modes. We find that voltage-controlled dielectrics can wrinkle in compression and extension, whereas charge-controlled dielectrics can only wrinkle in compression. We find that charge-controlled actuation is more stable than voltage-controlled actuation. Studies on waves in dielectric materials suggest the possibility of controlling the wave velocity by applying an appropriate electric field. This paves the way for applying acoustic non-destructive evaluation techniques to dielectric plates, a technique already used in purely elastic materials. Here we study Lamb wave propagation in dielectric plates subject to electrical and mechanical loadings. We look at the effects of the pre-stress, the electric field and the strain-stiffening on the wave characteristics. This work relies on theoretical and numerical treatments, using the multiphysics theory of nonlinear electro-elasticity, the incremental theory of small deformations and motions superposed on a large actuation, the Stroh formalism, the numerical resolution of boundary-value problems, and Finite Element simulations.

Modification and Extension of Volume Growth Theory for Soft Matter

Yangkun Du
Supervisors: Weiqiu Chen, Chaofeng Lü, Michel Destrade

Growth is a ubiquitous process in biological tissues and soft polymers, which involves volume changes, residual stress accumulation, and pattern evolution. As far as soft biological tissues are concerned, a better understanding of the true nature of growth can help explain related biological phenomena such as development, disease, ageing and death. Furthermore, many soft polymers can swell when immersed in a solvent, and investigating the true mechanism of their swelling may help us design self-assembly pattern devices, 4D bionic printing, and many other objects with promising applications.

Here, by relying on advanced continuum mechanics theory, we are able to build a rigorous and robust mathematical modelling of growth and to capture volume increase and/or shrinking, as well as the built-up in residual stress caused by growth. We focus on volume growth (as opposed to surface or tip growth), modelled within the framework of the multiplicative decomposition method. In particular, we decompose the total growth deformation multiplicatively into a pure growth deformation, corresponding to unconstrained growth, and a purely elastic deformation, ensuring that the grown body remains intact and continuous. In that framework, residual stress is interpreted as a rebalancing of the incompatibility caused by unconstrained growth and elastic deformation. In addition, we argue that because residual stresses are generated throughout the whole growth process, it is necessary to study how they promote or hinder growth and how they may generate instability patterns.

In summary, based on residual stress theory and on the multiplicative decomposition method, we modified the growth model to accommodate growth occurring between two arbitrary residually stressed

states. Also, with reference to nonlinear electro-elasticity theory, we extended the volume growth model to include electro-elastic effects. We showed that the modified and extended models are useful to capture some specific growth phenomena and to study some influential factors, such as initial residual stress and external electro-mechanical loads. Moreover, we showcased how volume growth modelling can help in designing health monitors, especially to assess the rupture risk of aneurysms. The modification, extension, and application of the volume growth model further promote the understanding and the use of growth and pattern formation of soft solids.

Optical variability in Late-M and Early-L dwarfs

Salam E. Hammeed Dulaimi
Supervisor: Aaron Golden

In this thesis, we report on over $\sim$ 160 hrs monitoring in I-band of multiple epochs from four ultra cool dwarfs, spanning the M tight binary dwarf 2MASS J1314203+132001A and L tight binary dwarf 2MASS J0746425+200032AB, the M9.5 dwarf BRI 0021-0214, and the L3.5 dwarf 2MASS J00361617+18211. This photometric campaign was carried out using the Galway Ultra-Fast Imager (GUFI) on the 1.8m Vatican Advanced Technology Telescope (VATT), on Mt. Graham, Arizona. All selected dwarfs exhibit periodic optical variability, where periods of both secondary components for our binary samples were newly discovered. We identify a newly discovered optical variability in the primary and secondary components of ultracool dwarf binary 2MASS J1314203+132001AB and 2MASS J0746425+200032AB, respectively. The optical data presented for both systems shows strongly correlated emissions in terms of phase and temporal variability. We have also shown the A and B variability signals of both dwarf binaries 2MASS J0746425+200032AB and 2MASS J1314203+132001AB, respectively, to be extremely consistent and stable over multiple epochs. This stability had seen in both radio and spectroscopic data, and the mechanism driving these processes in different parts of the electromagnetic spectrum could perhaps be fundamentally linked. We also investigate the orbital co-planarity of both binary dwarfs. Here the ability to deconvolve the inclination angle from the spectroscopic radial velocities, using direct estimates of the dwarf rotational periods, allows us to constrain the spin-orbit coupling of the binary system. In the case of the L dwarf binary 2MASS J0746425+200032AB, we calculate the equatorial inclination angle of the binary rotation axes are in alignment with the orbital plane of the system to within 10 degrees, consistent with solar-type binary formation mechanisms. For the M7 dwarf binary 2MASS J1314203+132001AB, due to missing parameters for the primary component, we investigate a tentative alignment of the spin-orbital axes of the A component. We find that the equatorial inclination angle of the secondary member spin axes is largely consistent with being aligned perpendicularly to the orbital plane. Finally, we find the rotation axes of the two single dwarfs are not perpendicular to our line of sight

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Edge colourings and Latin-like squares: Combinatorial structures arising from alternating sign matrices

Cian O'Brien
Supervisors: Rachel Quinlan and Kevin Jennings

An alternating sign matrix is a $(0, 1, -1)$-matrix in which the nonzero entries of each row and column alternate in sign, starting and ending with 1. An *alternating signed bipartite graph (ASBG)* is a bipartite graph G whose edges are coloured blue and red such that there is some ordering on the vertices of G for which the edges incident with each vertex of G alternate in colour, starting and ending with blue. We define a *difference-1 colouring* to be a 2-edge colouring of a graph such that each vertex is incident with one more blue edge than red. We call this colouring *configurable* if the resulting graph is an ASBG. This thesis investigates ASBGs by identifying a full set of necessary and sufficient conditions for a graph to have a difference-1 colouring, and necessary conditions for configurability.

The relationship between distinct difference-1 colourings of a particular graph is characterised,

and classes of graphs for which all difference-1 colourings are configurable are identified. One result of this research extends Hall's Matching Theorem by describing a necessary and sufficient condition for the existence of a subgraph H of a bipartite graph in which each vertex v of H has some prescribed degree $r(v)$. The more general idea of a difference-k colouring is also explored.

The concept of a Latin square was generalised by Brualdi and Dahl in 2018 by replacing permutation matrices in the decomposition of a Latin square with an *alternating sign hypermatrix (ASHM)*. The resulting object is an *alternating sign hypermatrix Latin-like square (ASHL)*. This thesis addresses some problems posed in Brualdi and Dahl's paper. The relationship between ASHMs with the same corresponding ASHL is characterised, and a construction is given for an $n \times n$ ASHL with the same entry occurring $\lfloor \frac{n^2+4n-19}{2} \rfloor$ times. This improves on the previous best construction, which achieved the same entry occuring $2n$ times.

A Statistical Decision Support System Incorporating Personalised Adaptive Reference Ranges for Longitudinal Monitoring in Prostate Cancer

Davood Roshan
Supervisors: Prof. John Newell, Dr. John Ferguson, Prof. Frank Sullivan

The overall aims of this thesis are to use modern approaches in Biostatistics to help clinicians diagnose Prostate Cancer (PCa) early, and treat effectively, and to help patients choose between treatment options. Biostatistics is both a primary and an enabling discipline, a fundamental requirement of all quantitative research, upon which the validity and integrity of research findings are dependent. This thesis encompasses both aspects. The primary (methodological) component involved the development of new and novel methods for generating adaptive ranges in longitudinal monitoring of biomarkers. The enabling component was to deliver on the requirements outlined by my funders (Prostate Cancer Institute (PCI) in the National University of Ireland, Galway), namely to build a decision support system that i) displays useful summary information of PCI data from several sources and ii) presents the results of several statistical analyses relating to treatment comparisons and outcomes in a manner that was informative to clinicians and patients.

The thesis is comprised of three Work Packages (WP). In the first WP, methods to generate personalised adaptive reference ranges (i.e. ranges that adapt and account for an individual's previous data) will be developed that allow clinicians to identify meaningful changes in an individual's blood test results more quickly compared to decision making using conventional normal ranges. Application of biomarker monitoring in elite sports will be presented also. Current techniques involve implementation of a Bayesian approach when the variability within individuals is assumed to be fixed. This thesis will further extend the current literature by accommodating different within individual variability structure that is more realistic, and will result in wider applicability. Additionally, the use of an approximate EM algorithm to produce computationally efficient adaptive ranges for large streaming datasets will also be proposed. A comprehensive simulation study will be undertaken to assess the performance of the methods proposed.

The second WP relates to identifying and assessing the main health outcomes following PCa treatment. In particular, the PCa treatment outcomes under different treatment options and based on different risk factors will be compared using suitable statistical methods.

Finally, in the third WP a modern statistical decision support system will be developed to enable patients make more informed and reliable decisions about their treatment choices.

To conclude, areas of further work across the three WPs will be outlined.

Zhu Reduction Theory for Vertex Operator Algebras on Riemann Surfaces

Michael Welby
Supervisor: Prof. Michael Tuite

In this thesis we first develop a recursive relation for n-point functions for Vertex Operator Super Algebras (VOSAs) on a genus two Riemann surface constructed by sewing two tori. This relation is used to develop formal differential equations for n-point

functions on a genus two surface, as well as for differential forms on this surface. We demonstrate the applications of this results for known examples and compare to existing results in the literature. In the second part, we develop a more general version of this identity for a Vertex Operator Algebra (VOA) on a general genus Riemann surface, using the Schottky uniformisation for the construction of a genus g Riemann surface and develop some geometric theory for the results that arise. We also apply these results to well-known examples of VOAs to obtain general genus identities for objects such as differential forms on a Riemann surface.

5 Staff profiles

Balbi, Valentina

Current research interests

My research focuses on developing mathematical models to predict the mechanical behaviour of soft tissues. I am interested in both experimental and theoretical aspects. Due to their complexity, soft tissues are difficult to test. From the experimental viewpoint, I am interested in developing robust and reliable testing protocols suitable for different tissues. Theoretically, I develop new continuum mechanics models to capture the non-linear mechanical behaviour of soft tissues.

Research outputs

Recent problems that I have investigated are mechanical behaviour of the brain during rotational heads impacts [3] and the early development of the brain [2]. From the theoretical viewpoint, another exciting topic I am currently working on is developing new viscoelastic models for soft tissues. I am particularly interested in the non-linear effects and the experimental validation and applications of the models [4, 1].

Recent publications

[1] M. Righi, V. Balbi *Foundations of viscoelasticity and application to soft tissues mechanics*, Chapter accepted in Nečas Center Series, 2021.

[2] V. Balbi, M. Destrade, A. Goriely *The mechanics of human brain organoids*, doi:10.1103/PhysRevE.101.022403. Physical Review E, 2020.

[3] V. Balbi, A. Trotta, M. Destrade, A. Ní Annaidh *Poynting effect of brain matter in torsion*, DOI: 10.1039/C9SM00131J. Soft Matter, 2019.

[4] V. Balbi, T. Shearer, W.J. Parnell, *A modified formulation of quasi-linear viscoelasticity for transversely isotropic materials under finite deformation*, DOI: 10.1098/rspa.2018.0231. Proc Roy Soc A, 2018.

Research activities

- So far I have supervised 7 Masters students, 2 Undergraduate students and 1 postdoctoral researcher;
- With Davide Riccobelli, I am co-organising a minisymposium on "Soft tissue biomechanics: From experiments to mathematical modelling" at the Italian Society of Applied and Industrial Mathematics (SIMAI) conference, Parma, Italy, June 2021;
- I was invited to give a series of lectures at the Doctoral school "Modelling of Biomaterials". Lectures topic: Mechanics of soft tissues, Kacov, Czech Republic, Feb 2020;

Berjamin, Harold

Current research interests

My current research deals with the mechanical modelling of soft biological tissues within the frameworks of nonlinear elasticity, viscoelasticity and poro-elasticity. These research activities are mainly motivated by the study of shock wave propagation in brain tissue, a topic which arises in the context of Traumatic Brain Injury (TBI). Recent results and ongoing developments are mostly of theoretical and computational nature. Parallel research works concern applications of the acoustoelasticity theory in solid mechanics.

Recent publications

[1] H. Berjamin, M. Destrade, W. J. Parnell, On the thermodynamic consistency of quasi-linear viscoelastic models for soft solids, *Mech. Res. Commun.* 111 (2021) 103648. `doi:10.1016/j.mechrescom.2020.103648`

[2] H. Berjamin, M. Destrade, A hyperbolic framework for shear sound beams in nonlinear solids, arXiv preprint (2020). `arxiv:2012.02742`

[3] H. Berjamin, Nonlinear plane waves in saturated porous media with incompressible constituents, arXiv preprint (2021). `arxiv:2101.09507`

Research activities

- *Grants*: This research is currently funded by a GOIPD fellowship of the Irish Research Council. A MSCA fellowship funded by the European Commission should start in October 2021.
- *Journal submissions*: 3.
- *Conferences*: 1. Elasticity Day, University of Cambridge, United Kingdom (2021, virtual).
- *Invited talks*: 4. School of Mathematics, NUI Galway, Ireland (2019); MACSI, University of Limerick, Ireland (2019); Postgraduate Modelling Group, NUI Galway, Ireland (2020); Laboratoire de Mécanique et d'Acoustique, Marseille, France (2020, virtual).
- *Papers refereed*: 19.
- *Memberships*: AFM-Euromech.

Burns, John

Current research interests

My current research interests are Algebra (Lie algebras, Lie groups, Weyl groups) and Differential Geometry (Homogeneous manifolds, Symmetric spaces). One current research project involves graded Lie Algebras and their application to the geometry of homogeneous submanifolds of noncompact symmetric spaces. These spaces are interesting as they contain a large class of Einstein manifolds.

Recent publications

[1] Burns, J. M.; Makrooni, M. A. Coxeter exponents and orthogonal complements of highest roots. Comm. Algebra 48 (2020), no. 7, 2833–2843.

[2] Burns, John M.; Makrooni, Mohammad A. Parabolic subroot systems and their applications. Glasg. Math. J. 62 (2020), no. 2, 355–366.

Carnevale, Angela

Current research interests

My research is primarily in the fields of algebraic and enumerative combinatorics. My work is often motivated by enumerative questions, mostly in algebra and geometry. The main research areas that I am interested in at the moment include matrix enumeration, permutation statistics and posets related to Coxeter groups.

Recent publications

[1] A. Carnevale, M. M. Schein and C. Voll, *Generalized Igusa functions and ideal growth in nilpotent Lie rings*, arXiv:1903.03090, 36 pp.

[2] A. Carnevale and M. Cavaleri, *Partial Word and Equality problems and Banach densities*, Adv. Math., 368 (2020), 107133, 16 pp.

[3] F. Brenti and A. Carnevale, *Odd length: odd diagrams and descent classes*, Disc. Math., 344 (2021), no. 5, 17 pp.

[4] F. Brenti, A. Carnevale and B. E. Tenner, *Odd diagrams, Bruhat order, and pattern avoidance*, arXiv:2009.08865, 15 pp.

[5] A. Carnevale and T. Rossmann, *Linear relations with disjoint supports and average sizes of kernels*, arXiv:2009.00937, 49 pp.

Research activities

- **Invited talks:** "Partial equality and word problems", *Groups in Galway, 2019*, NUI Galway, May 2019. • "Euler-Mahonian distributions and rational generating functions", *Oberseminar Groups and Geometry*, Bielefeld University, December 2019. • "Odd length in Weyl groups", *Program Seminar*, Institut Mittag-Leffler, Stockholm, February 2020. • "Generalized Igusa functions and growth in nilpotent Lie rings", *FPSAC 2020 Online*, July 2020. • "Growth in nilpotent Lie rings",*IMS September Meeting 2020*, Dublin City University, January 2021. • "Odd diagrams of permutations", *Workshop on Enumerative Combinatorics 2021*, University College Dublin, March 2021. • "An

odd tale of permutation statistics", *University of Washington Combinatorics and Geometry Seminar*, Seattle, April 2021.

- Junior Research Fellow during the programme *Algebraic and Enumerative Combinatorics*, Institut Mittag-Leffler, Stockholm, January 2020.
- External examiner for a PhD thesis (Rome, September 2020).
- Member of the Program Committee of the annual conference *FPSAC 2021*

Conroy Broderick, Hannah

Current research interests

My current research interests lie in modelling soft active materials such as dielectric elastomers and magnetoactive materials. These materials have many interesting applications in areas such as soft robotics, actuators and energy harvesting. More specifically, I am interested in modelling stability, wrinkling and wave propagation in electroactive and magnetoactive materials so to understand and predict their behaviour.

Recent publications

[1] H. Conroy Broderick, L. Dorfmann, M. Destrade. Electro-elastic Lamb waves in dielectric plates. *Extreme Mech. Lett.*, 39:100782, 2020.

[2] H. Conroy Broderick, M. Righi, M. Destrade, R.W. Ogden. Stability analysis of charge-controlled soft dielectric plates. *Int. J. Eng. Sci.*, 151:103280, 2020.

Research activities

- Started as a postdoctoral researcher working on magnetoactive materials in April 2021.
- Completed PhD in September 2020.
- Invited seminar: Nonlinear Solid Mechanics Group, MIT, October 2020.
- Talks at conferences: BAMC, April 2019 (invited); Castro, July 2019.
- Research visit to Luis Dorfmann (Tufts University) for two weeks in November 2019 to work on waves in dielectric plates.

Coughlan, Simone

Current research interests

My current research interests are in pathogen genomics (part of Irish Coronavirus Sequencing Consortium), metagenomic analysis of bacteria and viruses in the human gut and wider environment (wasterwater and soil), cancer genomics, and structural variation discovery and analysis.

Recent publications

[1] Jeffery, I. B., Das, A., O'Herlihy, E., Coughlan, S., Cisek, K., Moore, M., Bradley, F., Carty, T., Pradhan, M., Dwibedi, C., Shanahan, F., & O'Toole, P. W. Differences in Fecal Microbiomes and Metabolomes of People With vs Without Irritable Bowel Syndrome and Bile Acid Malabsorption doi:10.1053/j.gastro.2019.11.301 *Gastroenterology*, 158(4):1016-1028, 2020.

[2] Coughlan, S., Das, A., O'Herlihy, E., Shanahan, F., O'Toole, P. W., & Jeffery, I. B The gut virome in Irritable Bowel Syndrome differs from that of controls. doi:/10.1080/19490976.2021.1887719 *Gut Microbes*, 13(1):1-15, 2021.

Research activities

- Grant: HRB-TMRN Summer Scholarship (2021) for a student to do an eight-week internship to review current approaches for returning genomics results to clinical trial participants
- Students: Co-supervising 3 PhD students and supervising 1 MSc Biomedical Genomics MSc project
- General: Member of SFI funded Irish Coronavirus Sequencing Consortium. Bioinformatics processing covid-19 samples sequenced on Oxford Nanopore device at NUIG using ICHEC.

- Coordinated CRT in Genomics Data Science Residential Training Programme (Online due to Covid-19)
- Part of a team (Life Science Trainers; https://lifescitrainers.org/) that developed a Global Community survey to understand the experiences of instructors of short form courses. Analysis and publication of results in progress
- Joined newly established Open Educational Resources (OER) Working Group at NUIG
- Part of an ELIXIR group working on designing bioinformatics and genomics learning paths and supporting making training material meet the FAIR criteria, in my role as Training Coordinator for the Irish ELIXIR Node

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Cruickshank, James

Current research interests

I am currently working on projects in geometric rigidity theory, combinatorial topology, graph drawing and also automorphisms of p-groups.

Research outputs

3 journal submissions currently under review (links to arxiv versions below)

Recent publications

[1] James Cruickshank and Bernd Schulze. Symmetric contact systems of segments, pseudotriangulations and inductive constructions for corresponding surface graphs, 2020. available at: `https://arxiv.org/abs/2006.10519`

[2] Bill Jackson and James Cruickshank. Vertex splitting, coincident realisations and global rigidity of braced triangulations, 2020. available at: `https://arxiv.org/abs/2002.08680`

[3] James Cruickshank, Derek Kitson, Stephen C. Power, and Qays Shakir. Topological inductive constructions for tight surface graphs, 2021. available at: `https://arxiv.org/abs/1909.06545`

Research activities

During the period July 1 - Dec 31, 2019 I was on sabbatical leave.
Research visits

- Lancaster University: July 2019
- Lancaster University: October 2019

Workshop Participations:

- American Institute of Mathematics workshop on Rigidity and Fexibility of Microstructures, San Jose, November 2019.
- Heilbronn Workshop on Discrete Structures, Lancaster, January 2020.

Conference participations:

- Rigidity Workshop, Lancaster, June 2019
- Winter School on Geometric Constraint Systems, Fields Institute, Jan 2021 (online)
- Workshop on Progress and Open Problems in Rigidity Theory, Fields Institute, Jan 2021 (online)
- Mini-symposium on Materials and Periodicity, Fields Institute, Jan 2021 (online)
- Workshop on the Geometry of Circle Packings, Fields Institute, Jan 2021 (online)

Other activities: NUI Galway Departmental Colloquium, March 2021, organiser of Combinatorics reading group, refereeing and reviewing papers.

Destrade, Michel

Current research interests

I work on the modelling of dielectric and magneto-elastic elastomers, on acoustic waves travelling in soft tissues and in stressed solids, and on the torsion of rods.

Recent publications

[1] F. Xu, X.-Q. Feng, M. Destrade. Preface to the Special Issue on Instability and bifurcation in materials and structures. International Journal of Non-Linear Mechanics, 129 (2021) 103663.

[2] Y. Su, R.W. Ogden, M. Destrade. Bending control and instability of functionally graded dielectric elastomers. Extreme Mechanics Letters, 43 (2021) 101162.

[3] H. Berjamin, M. Destrade, W.J. Parnell. On the thermodynamic consistency of Quasi-Linear Viscoelastic models for soft solids. Mechanics Research Communications, 111 (2021) 103648.

[4] B. Wu, M. Destrade. Wrinkling of soft magnetoactive plates. International Journal of Solids and Structures, 208-209 (2021) 13-30.

[5] G. Zurlo, J. Blackwell, N. Colgan, M. Destrade. The Poynting effect. American Journal of Physics, 88 (2020) 1036.

Research activities

- *Current research grants*: 2 IRC postgraduate scholarships; 1 Marie Curie Postdoctoral Fellowship; 1 IRC postdoctoral Fellowship; 111 Project Visiting Grant from Zheijiang university; Ulysses Grant.
- *Conferences/Seminars:* 10+ (UL, Hangzhou, Nanjing, Shanghai, Oxford, Oberwolfach, Sheffield, Venice, etc.);
- *Graduate Courses:* 2 (Udine, Hangzhou);
- *Outreach talks:* 10+;
- *Appointments:* External Examiner (TUD); Reviews Editor (Proceedings of the Royal Society A); Contributing Editor (International Journal of Non-Linear Mechanics); Adjunct Professor of Mechanical Engineering (University College Dublin); Adjunct Professor of Mechanical Engineering (Zhejiang University); Directeur de Recherche, Institut d'Alembert, CNRS, Paris, France (on leave); International Brain Mechanics and Trauma Lab (Oxford); Biomechanics Research Centre (NUI Galway).

Egan, Ronan

Current research interests

Much of my recent work is in Coding Theory. I construct and analyse codes with different mathematical properties, such as self-orthogonal linear codes over finite fields, or propelinear codes - the codewords of which form a group. The rest of the time I work on problems in combinatorics and matrix theory. In particular I am interested in matrices describing combinatorial objects, and their spectra. Recently I have taken an interest in applying similar techniques to addressing problems in quantum information theory.

Research outputs

My five most recent publications which have appeared at least online are listed below.

Recent publications

[1] D. Crnković, R. Egan, A. Švob. Self-orthogonal codes from orbit matrices of Seidel and Laplacian matrices of strongly regular graphs. *Adv. Math. Commun.*, 14, 4, 591–602, 2020.

[2] R. Egan. Generalizing pairs of complementary sequences and a construction of combinatorial structures. *Discrete Math.*, 343, 5, 111795, 2020.

[3] D. Crnković, R. Egan, B. Rodrigues, A. Švob. LCD codes from weighing matrices. *Appl. Algebra Engrg. Comm. Comput.*, 32, 175–189, 2021.

[4] J. A. Armario, I. Bailera, R. Egan. Generalized Hadamard full propelinear codes. *Des. Codes. Cryptogr.*, to appear.

[5] D. Crnković, D. Dumičić Danilović, R. Egan, A. Švob. Periodic Golay pairs and pairwise balanced designs. *J. Algebraic Combin.*, to appear.

Research activities

- Many planned activities that didn't happen because of the thing.

Ellis, Graham

Current research interests

I am interested in computational topology and its applications to arithmetic, homotopy theory, and data analysis.

Recent publications

[1] G. Ellis. Computational Homotopy. *Oxford University Press*. 2019. xx+525 pp. ISBN: 978-0-19-883298-0; 978-0-19-883297-3

[2] G. Ellis. HAP, Homological Algebra Programming, Version 1.30 (2021). *Refereed GAP package*. https://gap-packages.github.io/hap

[3] G. Ellis and K. Killeen. Cohomology with local coefficients and knotted manifolds. *Journal of Symbolic Computation* 29pp. (April 2021). https://doi.org/10.1016/j.jsc.2021.04.004

[4] G. Ellis. Introductory computations in the cohomology of arithmetic groups. *Tbilisi Mathematics Journal*, in press (2021). https://arxiv.org/abs/2009.00313

Research activities

- Lead editor on *Cohomology, Geometry, Explicit Number Theory*, co-edited by P. Gunnels (Amherst), P. Elbaz-Vincent (Grenoble), H. Sengun (Sheffiled), which is to appear shortly as a special volume of the Tbilisi Mathematics Journal. http://tcms.org.ge/Journals/TMJ/announcement-for-special-issues/
- Co-organizing with P. Gunnells (Amherst) and P. Elbaz-Vincent (Grenoble) a workshop on *Lattices and Cohomology of Arithmetic Groups: Geometric and Computational Viewpoints* at the Banff International Research Station in October 2021. http://www.birs.ca/events/21/5-day-workshops/21w5205
- Active ediorial board member of: *Journal of Homotopy and Related Stuctures (Springer)*, *Homology, Homotopy, Applications (International Press)*, *Applicable Algebra in Engineering, Communication and Computing (Springer)*, *Tbilisi Mathematics Journal (De Gruyter)*.

Flannery, Dane

Current research interests

Linear group theory, algebraic design theory.

Recent publications

[1] A. S. Detinko, D. L. Flannery, A. Hulpke. Algorithms for experimenting with Zariski dense subgroups. *Exp. Math.*, 29(3):296–305, 2020.

[2] A. S. Detinko, D. L. Flannery, A. Hulpke. Experimenting with symplectic hypergeometric monodromy groups. *Exp. Math.*, published online June 2020. https://doi.org/10.1080/10586458.2020.1780516

[3] J. A. Armario, D. L. Flannery. Almost supplementary difference sets and quaternary sequences with optimal autocorrelation. *Cryptogr. Commun.*, 12:757–768, 2020.

[4] A. S. Detinko, D. L. Flannery, A. Hulpke. The strong approximation theorem and computing with linear groups. *J. Algebra*, 529:536–549, 2019.

[5] A. S. Detinko, D. L. Flannery. Linear groups and computation. *Expo. Math.*, 37(4):454–484, 2019.

Research activities

- Invited speaker, *Sequences, codes and designs (ArasuFest)*, Kalamata, Greece, 1–4 August, 2019.
- Invited speaker, *Computational and Algorithmic Methods*, Isaac Newton Institute for Mathematical Sciences, Cambridge, 27–31 January, 2020.
- Research in Pairs, MFO, Oberwolfach Research Institute for Mathematics, Germany, 9–22 August, 2020

- Research-in-Pairs, Centre International de Rencontres Mathématiques Luminy, France (originally 6–17 April, 2020; re-scheduled 23 August–3 September, 2021).
- Mentor, Irish Research Council Fellow, GOIPD/2018/304.
- Member of the Engineering and Physical Sciences Research Council UK Associate Peer Review College.
- Reviewer, zbMATH, European Mathematical Society.

Golden, Aaron

Current research interests

- Magnetic activity in stellar/planetary magnetospheres & atmospheres, and the impact of space weather on habitability.
- Quantifying/predicting the biosphere's response to climate change.
- Data-intensive imaging science in medicine & remote sensing.

Recent publications

[1] P. Ciliegi, G. Agapito, et al. MAORY: A Multiconjugate Adaptive Optics RelaY for ELT. *The Messenger*, 182:13–16, March 2021.

[2] S. Karki, K. French, V. McCarthy, et al. In-Situ Validation of Water Quality Algorithms and Monitoring of Irish Lakes using Sentinel 2 Imagery. In *EGU General Assembly Conference Abstracts*, EGU General Assembly Conference Abstracts, page 2223, May 2020.

[3] L. King, A. Flaus, E. Holian, et al. Survival outcomes are associated with genomic instability in luminal breast cancers. *PLoS One*, 16(2):e0245042, 2021.

[4] K. M. Schoenrock, K. M. Chan, T. O'Callaghan, et al. A review of subtidal kelp forests in Ireland: From first descriptions to new habitat monitoring techniques. *Ecol Evol*, 10(13):6819–6832, Jul 2020.

[5] Q. Zhang, G. Hallinan, W. Brisken, et al. Multiepoch VLBI of L Dwarf Binary 2MASS J0746+2000AB: Precise Mass Measurements and Confirmation of Radio Emission from Both Components. *The Astrophysical Journal*, 897(1):11, July 2020.

Research activities

- New Funding Awards
  Health Research Board (COVID-19 Rapid Response Research & Innovation Programme), Science Foundation Ireland (Future Innovator Prize 2019 - 'Seed Round'), Irish Research Council (Government of Ireland Postdoctoral Fellowship), Irish Centre for High End Computing (Priority Access to High-Performance Computing (HPC) for COVID-19 Research)
- Existing Research Grants
  Environmental Protection Agency STRIVE award 2018-W-DS-33 - *GRACE Monitoring of Groundwater over Ireland*, Environmental Protection Agency STRIVE award 2018-W-MS-35 - *The Diversity and Resilience of kelp ecosystems in Ireland*, Environmental Protection Agency STRIVE award 2017-W-MS-30 - *Remote Sensing of Irish Surface Waters*
- Research Supervision
  Postdoctoral Fellows: 2
  Current PhD Students: 4
  Completed PhD Students: 1
- Expert Reviewer Activities
  European Southern Observatory, Observing Programmes Committee
  FCT – Fundação para a Ciência e a Tecnologia (Portugal), 2021 Call for R&D Projects
- Memberships
  Institute of Physics
  American Astronomical Society
  International Astronomical Union
  Royal Astronomical Society

Holian, Emma

Current research interests

Prognostic models in Breast Cancer, in particular; variable selection in survival models for data with various missingness mechanisms, modelling treatment outcome on longitudinal biomarkers. Statistical methods in Genomics Data Science; hypothesis testing in Microarray analysis, Next-Generation Sequencing (NGS), genome Copy Number Alterations, with focus on the error structure, improved standard error estimators, distribution estimation and multiple testing adjustment techniques. Statistical challenges in environmental impact studies and climate data; challenges of left-censored distributions in groundwater data. Classification and cluster analysis of longitudinal data profiles via Regression Cluster Model (RCM), mixture modelling using generalized linear mixed models and penalized smoothing models.

Recent publications

[1] L. King, A. Flaus, E. Holian, A.Golden. Survival Outcomes are Associated with Genomic Instability in Luminal Breast Cancers. *Plos One*, 2021.

[2] E. McGrory, E. Holian, L. Morrison. Assessment of groundwater processes using censored data analysis incorporating non-detect chemical, physical, and biological data. *Journal Of Contaminant Hydrology*, 235, 2020.

[3] B.M. Moloney, et.al. Investigating the Potential and Pitfalls of EV-Encapsulated MicroRNAs as Circulating Biomarkers of Breast Cancer. *Cells*, 9(141), 2020.

[4] V. Arabkari, et.al. Relative and Absolute Expression Analysis of MicroRNAs Associated with Luminal A Breast Cancer-A Comparison. *Pathology & Oncology Research*, 1-12, 2020.

[5] A. McGuire, et.al. Prospective Assessment of Systemic MicroRNAs as Markers of Response to Neoadjuvant Chemotherapy in Breast Cancer. *Cancers*, 12(7), 2020.

Research activities

Ph.D Student Supervision (3): Maxwell Paganga - NBCRI, Lydia King - SFI CRT Genomics Data Science, Olga Kalinina - NBCRI.
Affiliations: Biostatistics and Bioinformatics Research Cluster, Biostatistics Unit HRB CRFG, INSIGHT NUIG, ISA, International Biometric Society.

Howard, Mark

Current research interests

I'm primarily interested in quantum information theory, specifically:

- Stabilizer formalism (generalization to d-level systems, quantum error-correcting codes, Gottesman-Knill theorem)
- Clifford group and classical simulability of restricted quantum circuits
- Discrete Wigner functions (negative quasiprobabilities, relationship with GK theorem)
- Magic state distillation and Quantum Fault tolerance more generally
- Nonlocality & Contextuality, Mutually unbiased bases, SIC-POVMs, foundations of quantum theory

Research outputs

1 Pierre-Emmanuel Emeriau, Mark Howard, Shane Mansfield
Quantum Advantage in Information Retrieval
arXiv:2007.15643 (2020).

2 Michael Beverland, Earl Campbell, Mark Howard, Vadym Kliuchnikov
Lower bounds on the non-Clifford resources for quantum computations
Quantum Sci. Technol. 5 035009 (2020).

3 S. Bravyi, D. Browne, P. Calpin, E. Campbell, D. Gosset and M. Howard,
Simulation of quantum circuits by low-rank stabilizer decompositions.
Quantum 3, 181 (2019).

4 M. Howard, and E. T. Campbell,
Application of a resource theory for magic states to fault-tolerant quantum computing
Physical review letters 118 9 090501 (2017).

5 M. Howard, J. Wallman, V. Veitch, and J. Emerson,
Contextuality supplies the "magic" for quantum computation.
Nature, 510, 351 (2014).

Research activities

- PhD student Billy Ray won a College of Science and Engineering scholarship
- Paper 1 above was accepted for an oral presentation at
  - Quantum Physics and Logic 2020
  - QTurn 2020
- Invited Speaker for ZX-calculus seminar April 2020 "at" University of Oxford

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Kerin, Martin

Current research interests

My research is primarily aimed at understanding Riemannian manifolds with either positive or non-negative sectional curvature. This often leads to the use of techniques from, and to deep questions emerging in, areas such as Lie Groups, Representation Theory, Algebraic and Differential Topology, and Rational Homotopy Theory. Recently, much of my research has involved manifolds which can be decomposed as the union of two disk-bundles.

Recent publications

[1] F. Galaz-García, M. Kerin and M. Radeschi, *Torus actions on rationally elliptic manifolds*, Math. Z. **297** (2021), 197–221

[2] J. Harvey, M. Kerin and K. Shankar, *Semi-free actions with manifold orbit spaces*, Documenta Math. **25** (2020), 2085–2114

[3] S. Goette, M. Kerin and K. Shankar, *Fake lens spaces and non-negative sectional curvature*, Differential Geometry in the Large, LMS Lecture Note Series (463), Cambridge Univ. Press, 2020, 285–290

[4] S. Goette, M. Kerin and K. Shankar, *Highly connected 7-manifolds and non-negative sectional curvature*, Ann. of Math. **191** (2020), 829–892

Research activities

- Founded the Irish Geometry Seminar
- Nominated for President's Early Stage Researcher Award
- *Conferences organised:* 2 (Curvature and Global Shape (Münster); Groups in Galway meets the Irish Geometry Seminar (NUIG) (postponed))
- *Seminars organised:* 1 (Irish Geometry Seminar)
- *Research talks:* 10 (Bath; CUNY; Durham; Irish Maths Society; Notre Dame; NUIG; Maynooth; Peking University; UPenn; Virtual Seminar on Geometry with Symmetries)
- *Conferences attended:* 4 (Durham; Notre Dame; Münster; Irish Maths Society)
- *Preprints/submissions:* 3
- *Referee reports:* 3
- *Reviews for Mathematical Reviews:* 2

Madden, Niall

Current research interests

I am interested in the development, analysis and programming of algorithms for computing approximate solutions to partial differential equations, particularly those whose solutions feature boundary or interior layers, and mainly by finite element methods. I'm especially interested in mesh generation methods, and "fast" solvers of linear systems.

Research outputs

Recent publications

[1] James H. Adler, Scott MacLachlan, and Niall Madden. First-order system least squares finite-elements for singularly perturbed reaction-diffusion equations. In *Large-scale scientific*

computing, volume 11958 of *Lecture Notes in Comput. Sci.*, pages 3–14. Springer, Cham, 2020.

[2] Hormoz Jahandari, Scott MacLachlan, Ronald D. Haynes, and Niall Madden. FE modelling of geophysical electromagnetic data with goal-oriented *hr*-adaptivity. *Comput. Geosci.*, 24(3):1257–1283, 2020.

[3] Stephen Russell and Niall Madden. Analysis of a Galerkin finite element method applied to a singularly perturbed reaction-diffusion problem in three dimensions. *Int. J. Numer. Anal. Model.*, 17(3):297–315, 2020.

[4] Thái Anh Nhan and Niall Madden. An analysis of diagonal and incomplete Cholesky preconditioners for singularly perturbed problems on layer-adapted meshes. *J. Appl. Math. Comput.*, 65(1-2):245–272, 2021.

[5] N. Poddar, K.K. Mondal, and N. Madden. Layer-adapted meshes for solute dispersion in a steady flow through an annulus with wall absorption: Application to a catheterized artery. *Korea-Aust. Rheol. J.*, 33(1-2):11–24, 2021.

Research activities

- I am currently supervising two PhD students: Faiza Alssaedi, and Róisín Hill (IRC Scholar).
- In recent times, I have refereed manuscripts for Calcolo, IMA Journal of Numerical Analysis, SIAM Journal on Numerical Analysis, SIAM Journal on Scientific Computing, and numerous others. I continue to serve as an associate editor of Numerical Algorithms (Springer).
- In the past 24 months I have presented at conferences and workshops in Ireland, UK, India, and Spain.

McCluskey, Aisling

Current research interests

My current research interests revolve around generalising the familiar notions of betweenness and relativeness closeness in Euclidean geometry to the natural metric space context where ideas such as equidistance, midsets, Voronoi regions raise some interesting questions.

Recent publications

[1] J. Cao, A. McCluskey Topological transitivity in quasi-continuous dynamical systems. *Topology and its Applications*, to appear (2020)

[2] D. Anderson, P. Bankston, A. McCluskey Convexity in topological betweenness structures. *Topology and its Applications*, to appear (2021)

Research activities

- April 2019: Invited seminar in University of Auckland's Mathematics Education Seminar series
- June 2019: Co-organiser with host Jorge Bruno of 21st Galway Topology Colloquium at the University of Winchester
- November 2019: Host of one-day British Society for Research into Learning Mathematics (BSRLM) conference at QUB. This arose due to the sudden and serious ill-health of the QUB host; approved to deputise by the BSRLM executive.

Mc Gettrick, Michael

Current research interests

I am interested mainly in quantum computation and quantum information, and therein mainly in quantum walks and quantum games. A different current research activity of mine is in the mathematics of transport, specifically on optimizing tram networks in cities with different "shapes". In 2021 I initiated a collaboration with a researcher at the University of Plymouth on quantum music.

Recent publications

[1] Michael Mc Gettrick. The role of city geometry in determining the utility of a small urban light rail/tram system. *Public Transport*, 12(1):233–259, Jan 2020.

[2] Berry Groisman, Michael Mc Gettrick, Mehdi Mhalla, and Marcin Pawłowski. How quantum information can improve social welfare. *IEEE Journal on Selected Areas in Information Theory*, 1(2):445–453, 2020.

[3] Dan Li, Michael Mc Gettrick, Yu-Guang Yang, Juan Xu, and Yuan Wang. Quantum walks with memory provided by parity of memory. *International Journal of Theoretical Physics*, 59(6):1934–1943, Jun 2020.

[4] Victoria Sánchez Muñoz and Michael Mc Gettrick. Nash equilibria in certain two-choice multi-player games played on the ladder graph. *International Game Theory Review*, page 2050020, Jan 2021.

Research activities

- Research sabbatical, Jan—Jun 2019, Extended visits to ■ Nanjing University of Aeronautics and Astronautics, quantum walks collaboration with D. Li, ■ Nottingham Trent University, quantum walks collaboration with C. Wilmott, ■ Mathematisches Forschungsinstitut Oberwolfach (Germany), where I organized a "Research in Pairs" quantum games collaboration with researchers from Poland/France/UK, ■ the Institute of Theoretical and Applied Informatics, Polish Academy of Sciences, quantum games collaboration with J. Miszczak.

- Currently supervising one Ph.D. student.

- Talks: (1) COST (European Cooperation in Science and Technology) final meeting on *Reversible Computation*, University of Malta (Mar. 2019) (2) Nanjing University of Aeronautics and Astronautics (May 2019), (3) the Institute of Theoretical and Applied Informatics, Polish Academy of Sciences, Gliwice (Aug. 2019), (4) NUIG School of Maths Seminar (Dec. 2019).

- Conferences: 9th International Conference on Quantum Simulation and Quantum Walks (Marseille, Jan. 2020), a number of online conferences during the pandemic.

- I am active on both **math***overflow*.net (reputation 131, 4 bronze badges) and `math.StackExchange.com` (reputation 141, 5 bronze badges).

- I carried out a "Short Term Scientific Mission" to Nottingham Trent University in 2019.

- Reviews: Two paper manuscripts for the International Journal of Theoretical Physics, one book manuscript for Cambridge University Press, grant applications for the Leverhulme Trust (UK) and the Engineering and Physical Sciences Research Council (UK).

Newell, John

Current research interests

My current research interests are in the development and application of statistical methods in clinical research, sports science, sports analytics and in translational statistics.

Research outputs

Bruinvels, Georgie, Esther Goldsmith, Richard Blagrove, Andrew Simpkin, Nathan Lewis, John Newell, et al. (2021) Prevalence and frequency of menstrual cycle symptoms are associated with availability to train and compete: a study of 6812 exercising women recruited using the Strava exercise app. British Journal of Sports Medicine 55, no. 8: 438-443.

Roshan D, Ferguson J, Pedlar CR, Simpkin A, Wyns W, Sullivan F, Newell, J. (2021) A comparison of methods to generate adaptive reference ranges in longitudinal monitoring. PloS ONE 16(2).

Sheill G, Guinan E, O'Neill L , Newell J, et al. (2021) Prehabilitation during a pandemic: preoperative exercise to improve fitness in patients undergoing complex surgery for cancer of the lung or oesophagus, the PRE-HIIT trial: an updated study protocol. HRB Open Res 2021, 4:4

Contessotto P, Orbanić D, Da Costa M, Jin C, Owens P, Chantepie S, Chinello C, Newell J, Magni F, Papy-Garcia D, Karlsson NG, Kilcoyne M, Dockery P, Rodríguez-Cabello JC, Pandit

A.(2021). Elastin-like recombinamers-based hydrogel modulates post-ischemic remodeling in a non-transmural myocardial infarction in sheep. Sci Transl Med. Feb 17;13(581)

Casey, D., Gallagher, N., Devane, D. et al. (2020). The feasibility of a Comprehensive Resilience-building psychosocial Intervention (CREST) for people with dementia in the community: protocol for a non-randomised feasibility study. Pilot Feasibility Stud 6, 177

Research activities

Grants: CURAM (funded PI), Insight (funded PI), HRB Primary Care Clinical Trials Network Ireland (Biostatistician), HRB D2 Now Trial (Biostatistician), HRB CREST Trial ((Biostatistician). Graduate students: 1 Postdoctoral Researcher, 4 PhD students, 1 MSc (Research) student External examiner: UCC MSc in Data Science and Analytics Awards: FC Barcelona Innovation Hub Conference: Analytics in Sports Tomorrow – Research papers winner: Predicting and Individualising Training Load using historical GPS data in Elite Soccer. Dr. Kenny McMillan, Dr. Andrew Simpkin, Dr. Brian Moore, Prof. John Newell

Our R package 'DynNom' for generating Dynamic Nomograms reached 30,000 downloads in February 2020. Amirhossein Jalali, Davood Roshan, Alberto Alvarez-Iglesias and John Newell (2019): DynNom: Visualising Statistical Models using Dynamic Nomograms. R package version 5.0.1.

O'Brien, Cian

Current research interests

My main objects of study are alternating sign matrices, which are $(0, \pm 1)$-matrices in which the nonzero entries of each row and column alternate in sign, beginning and ending with 1. Particular objects of interest to me include alternating signed bipartite graphs and related edge colouring problems, alternating sign hypermatrices and related Latin-like square structures, finite subgroups of $GL(n, \mathbb{Q})$ generated by alternating sign matrices, and algebraic structures relating to alternating sign matrices when their entries are considered to be elements of F_3.

Recent publications

[1] C. O'Brien. Alternating sign hypermatrix decompositions of Latin-like squares. *Advances in Applied Mathematics*, 121, 2020.

[2] C. O'Brien, K. Jennings, R. Quinlan. Alternating signed bipartite graphs and difference-1 colourings. *Linear Algebra and Its Applications*, 604:370-398, 2020.

Research activities

- Currently conducting research as a postdoctoral researcher with R. Quinlan, funded by NUI Galway.
- Completed my PhD in 2020, supervised by R. Quinlan and K. Jennings. Thesis title; "Edge Colourings and Latin-like Squares: Combinatorial Structures Arising from Alternating Sign Matrices".
- Presented at the British Combinatorial Conference 2019 in University of Birmingham, invited speaker at the International Linear Algebra & Matrix Theory Workshop 2019 in UCD, invited speaker at the IMS meeting 2019 in NUI Galway.

Ó Broin, Pilib

Current research interests

My research interests lie primarily in clinical/translational bioinformatics with a particular focus on the development and application of machine learning methods for genomic data in the cancer, immunology, and neuroscience domains.

Research outputs

[1] Computational identification of variables in neonatal social communication predictive for post-pubertal social behaviors in a mouse model of 16p11.2 deletion. Mitsuteru Nakamura*, Kenny Ye*, Mariel Barbachan e Silva*, [...], Pilib Ó Broin, Mitsuyuki Matsumoto, Noboru Hiroi. *Molecular Psychiatry*, 2021.

[2] Genes influenced by MEF2C contribute to neurodevelopmental disease via gene expression changes that affect multiple types of cortical excitatory neurons'. Donna Cosgrove, Laura Whitton, Laura Fahey, Pilib Ó Broin, Gary Donohoe, Derek W. Morris. *Human Molecular Genetics*, 2020. DOI: 10.1093/hmg/ddaa213.

[3] Genes regulated by BCL11B during T cell development are enriched for de novo mutations found in schizophrenia patients. Laura Fahey, Gary Donohoe, Pilib Ó Broin*, Derek Morris*. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics* 183B:370–379, 2020.

[4] A Particle Swarm Optimisation-optimised ensemble for Antibody-Mediated Rejection status prediction in kidney transplant patients. Mariel Barbachan e Silva and Pilib Ó Broin. *IEEE Congress on Evolutionary Computation 2020 (CEC2020)*

Research activities

- My research group currently consists of: 6 PhD students, 4 Biomedical/Computational Genomics MSc students, and 1 Chemoinformatics and Toxicology MSc student.
- Research outputs: 8 journal articles, 2 conference papers, and 7 conference abstracts submitted
- Funded by: NUIG OER development scheme, PI: €3k, DTIF, Co-I: €6.8M, EC (MCSA-ITN), Collaborator: €525k, IRC (Ulysses), PI: €2.5k, Údaras na Gaeltachta, Co-I: €31k
- Research visits: Awarded funding under the ERASMUS+ scheme to travel to the Barcelona Supercomputing Centre (BSC)
- Invited reviewer: Lung Cancer, Briefings in Bioinformatics, Nature Communications, Journal of Psychiatric Research, Irish Centre for High-End Computing (ICHEC)
- PhD examiner: Marcos Cardinot Meira Junior (PhD Computer Science, NUIG), Orges Koki (PhD Bioinformatics, University of Glasgow), PhD Committee Chair: Alexandre Pelettier (PhD candidate, Bioinformatics and Systems Biology, Institut Pasteur de Lille)
- Memberships: European Association for Cancer Research (EACR), International Society for Computational Biology (ISCB), Irish Society for Human Genetics (ISHG), European Society for Human Genetics (ESHG), Marie Curie Alumni Association (MCAA), ELIXIR Machine Learning Focus Group

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Ó Fionnagáin, Dúalta

Current research interests

My primary research interest is in **radio astronomy**, which can be sub-divided into three different categories. Firstly, I am currently working on detecting **planetary lightning** using ground-based radio telescopes such as LOFAR and OVRO-LWA. This could potentially be extended to exoplanets, which would have significant implications for exoplanetary atmospheric research.

Secondly, I am interested in **low-mass stars** (similar to our Sun), their winds, coronae, and magnetic fields. I quantify these phenomena using 3D magnetohydrodynamic simulations. Combined with radio observations, we can achieve a better understanding of stellar atmospheres and their effects on exoplanets and habitability.

Finally, I have a keen interest in **exoplanets** and **star-planet interactions**. I research the ways in which these interactions can happen to help us understand the star-planet environment and how we can advance observations to measure this phenomena.

Recent publications

[1] D. Ó Fionnagáin, et al. λ And: a post-main-sequence wind from a solar-mass star. *MNRAS*, 500:3438-3453, 2021.

[2] C. Folsom, & D. Ó Fionnagáin, et al. Circumstellar environment of 55 Cancri. The super-Earth 55 Cnc e as a primary target for star-planet interactions. *Astronomy & Astrophysics*, 633, A48, 6, 2020

[3] D. Ó Fionnagáin. The winds of low-mass stars and solar-wind evolution. *PhD Thesis*, TCD, 2020

Research activities

- I started my IRC Postdoctoral Fellowship in October 2020
- Member of radio telescope working groups including I-LOFAR and OVRO-LWA
- Member of the BCool consortium observing the magnetic fields of cool stars

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Pfeiffer, Götz

Current research interests

Complex hyperplane arrangements and their symmetry groups, various algebras related to these arrangements and their roles as modules for the group and as cohomology rings, Hecke algebras of complex reflection groups and their centers.

Recent publications

[1] J. Matthew Douglass, Götz Pfeiffer and Gerhard Röhrle. On the Invariants of the Cohomology of Complements of Coxeter arrangements. *J. Algebra* **558** (2020) 336–349.

[2] J. Matthew Douglass, Götz Pfeiffer and Gerhard Röhrle. Invariants and semi-invariants in the cohomology of the complement of a reflection arrangement. arXiv:2009.12847.

Research activities

- Graduate Students: 1
- Papers refereed: 11.
- Conferences: Groups in Galway 2019, 10–11 May 2019, Galway, Ireland; Workshop "Hyperplane Arrangements and Reflection Groups", September 23–27, 2019, Leibniz-Universität Hannover, Germany; Groups in Galway 2020, 9–11 September 2020, online; Nikolaus Conference 2020, 11–12 December 2020, online; Workshop "Logarithmic Vector Fields and Freeness of Divisors and Arrangements: New perspectives and applications", Mathematisches Forschungsinstitut Oberwolfach, January 24–30, 2021, online.
- Invited Talks: *Symmetries in Music* (May 2019, Pint of Science, Galway, Ireland); *On Computations in the Orlik-Solomon Algebra of a Reflection Arrangement* (June 2019, Oberseminar Algebra, Universität Stuttgart, Germany); *Bisets and the Double Burnside Algebra of a Finite Group* (July 2019, Oberseminar Lie-Theorie, Ruhr-Universität Bochum, Germany); *On Computations in the Orlik-Solomon Algebra of a Reflection Arrangement* (September 2019, Workshop "Hyperplane Arrangements and Reflection Groups", Leibniz-Universität Hannover, Germany); *On Computations in the Orlik-Solomon Algebra of a Reflection Arrangement* (November 2019, School of Mathematics and Computer Science, University of Wolverhampton, UK).
- Editorial Board Member: Journal of Symbolic Computation; Mathematical Proceedings of the Royal Irish Academy.
- Member: Irish Mathematical Society; American Mathematical Society.

Pfeiffer, Kirsten

Current research interests

My research interests focus on educational interventions to enhance students' creative reasoning skills and ultimately the learning of mathematical argumentation and proof. I'm interested in task design in the teaching of mathematics at university level, in particular in students' practice of proof evaluation exercises and possible learning effects of these. I'm also interested in the role of mathematics support centres from a sociocultural point of view. More recently I have been investigating in research about accessibility of online maths resources, in particular for students with learning difficulties.

Recent publications

[1] K. Pfeiffer. Mathematics support centres from a sociocultural point of view. *MSOR Connections*, (Vol. 17, No. 3), 2019.

Research activities

- As the chair of the Irish Maths Learning Support Network (IMLSN) I have been organising a series of four online workshops on *Maths Support in Covid Times* (June 2020, Sept 2020, Jan 2021, May 2021). One of the outcomes of the first two of these workshops was that participants highlighted the demand for shared online learning resources.

- Inspired by this, I am leading a project with the aim to provide shared maths support learning resources on the IMLSN website. The National Forum for the Enhancement of Teaching and Learning in Higher Education supports this project with funding for the first three months. We anticipate to provide well chosen and quick & easy to access resources for foundation and many first year mathematics courses by May 2021. We aim to monitor the use of the project outputs via website analytics and by surveying members and students. These analytics, feedback and observations may highlight changes in students' attitudes towards online resources since Covid-19 restrictions in 2020.

- In collaboration with colleagues from the University of Birmingham, TU Dublin and the University of Maynooth, we have developed an accrediting systems of training for postgraduate tutors and lecturers in STEM. We have presented this initiative at several conferences in 2019 and are currently writing a paper about it.

Quinlan, Rachel

Current research interests

My research interests are mostly in algebra and combinatorics, including linear algebra over rings and fields, connections between matrices and graphs, and representation theory. I am also interested in the teaching and learning of mathematics in higher education. Objects of current attention include systems of linear equations over principal ideal domains (with Fernando Szechtman and Moumita Shau at the University of Regina), and alternating sign matrices of finite multiplicative order (with Cian O'Brien at NUI Galway).

Research outputs

- Cian O'Brien, Kevin Jennings and Rachel Quinlan, Alternating signed bipartite graphs and difference-1 colourings. *Linear Algebra Appl.* 604 (2020), 370–398.

- Olga O'Mahony and Rachel Quinlan, Exponent-critical primitive graphs and the Kronecker product. *Electron. J. Graph Theory Appl. (EJGTA)* 7 (2019), no. 2, 329–347

- Hieu Ha Van and Rachel Quinlan, Almost-nonsingular entry pattern matrices. *Linear Algebra Appl. 578 (2019)*, 334–355.

- James Cruickshank, Rachel Quinlan and Fernando Szechtman, Hermitian and skew hermitian forms over local rings. *Linear Algebra Appl.* 551 (2018), 147–161.

- Olga O'Mahony and Rachel Quinlan, Edge-minimal graphs of exponent 2. *Linear Algebra Appl.* 542 (2018), 66–83.

Research activities

- I am the co-chair of the local and scientific organising committees for the 24th Conference of the International Linear Algebra Society, which is scheduled to take place in Galway in June 2022 (deferred from 2020).

- In 2020 I was the external examiner for the PhD degrees of Conor Finnegan (University College Dublin) and Lorenzo Ciardo (University of Oslo).

- Referee for *LAA*, *EJGTA*, *Open Math.*

Roshan, Davood

Current research interests

My primary research interest is in the longitudinal analysis of clinical biomarkers. In particular, in my PhD, I developed individualised and dynamic reference ranges for clinical biomarkers that are recorded longitudinally over time. My research domain includes but not limited to medicine, sport, engineering, finance and etc. I also have special interest in translational statistics, data visualisations and data science with a focus on developing predictive tools.

Research outputs

- Roshan, D., Ferguson, J., Pedlar, C. R., Simpkin, A., Wyns, W., Sullivan, F., & Newell, J. (2021). *A comparison of methods to generate adaptive reference ranges in longitudinal monitoring.* PLoS One. 2021 Feb 19;16(2):e0247338. doi: 10.1371/journal.pone.0247338.

- Roshan, D., Joyce, K., Woulfe, P., Gorakati, P. R., Stock, R., & Sullivan, F. J. (2021). *Live implant dosimetry may be an effective replacement for postimplant computed tomography in localized prostate cancer patients receiving low dose rate brachytherapy. Brachytherapy.*

- Jalali, A., Roshan, D., Moghaddam, S., & Newell, J. (2020). *survRatio: Estimating, Comparing and Visualising Time to Event Data.* R package version 0.1 https://CRAN.Rproject.org/package=survRatio

- Jalali, A., Alvarez-Iglesias, A., Roshan, D., & Newell, J. (2019). *Visualising statistical models using dynamic nomograms.* PloS one, 14(11), e0225253.

Research activities

- Successfully defended my Phd thesis in 2020 entitled as 'A Statistical Decision Support System Incorporating Personalised Adaptive Reference Ranges for Longitudinal Monitoring in Prostate Cancer'.

- Collaboration with Prostate Cancer Institute, NUI Galway for delivering Value Based Healthcare in Prostate Cancer.

- I continue to serve as the executive member of Young Irish Statistical Association where we organise the Inaugural Young-ISA meeting; twitter poster conference; and Young-ISA monthly webinar series.

- Memberships: Young-ISA, Irish Statistical Association, International Society for Clinical Biostatistics, International Biometric Society, Statistical Modelling Society.

Rossmann, Tobias

Current research interests

I am interested in asymptotic, computational, and enumerative aspects of algebra. In recent years, my main focus has been on the study of a class of zeta functions introduced in [1]. These zeta functions have applications in the study of orbit, conjugacy class, and representation growth of groups.

Recent publications

[1] T. Rossmann, *The average size of the kernel of a matrix and orbits of linear groups,* Proc. Lond. Math. Soc. (3) 117 (2018), no. 3, 574–616.

[2] T. Rossmann, *The average size of the kernel of a matrix and orbits of linear groups, II: duality*, J. Pure Appl. Algebra 224 (2020), no. 4, 28 pp.

[3] T. Rossmann and C. Voll, *Groups, graphs, and hypergraphs: average sizes of kernels of generic matrices with support constraints*, arXiv:1908.09589, 109 pp.

[4] A. Carnevale and T. Rossmann, *Linear relations with disjoint supports and average sizes of kernels*, arXiv:2009.00937, 49 pp.

[5] T. Rossmann, `Zeta`*, a SageMath package for computing local and topological zeta functions, version 0.4.1, 2021.* See `https://github.com/torossmann/Zeta`

Research activities

- **Invited talks:** "Tensors in Enumeration: Counting orbits and conjugacy classes" and "Groups, growth, and graphs", *Tensors: Algebra-Computation-Applications (TACA)*, University of Colorado Boulder and Colorado State University (Rocky Mountain Campus), June 2019. ⊗ "Groups, growth, and graphs", *Annual meeting of the Irish Mathematical Society*, NUI Galway, September 2019. ⊗ "Groups, growth, and geometry", *Buildings, Varieties, and Applications*, Max Planck Institute for Mathematics in the Sciences (Leipzig), November 2019. ⊗ "Class numbers of groups associated with (co)graphs", *Oberseminar Groups and Geometry*, Bielefeld University, December 2019. ⊗ "Growth of class numbers of unipotent groups", *Groups, representations and applications: new perspectives. Computational and algorithmic methods*, Isaac Newton Institute for Mathematical Sciences (Cambridge), January 2020. ⊗ "Zeta functions of groups, algebras, and modules: toric computations", *Global Virtual SageDays 110*, October 2020.
- Referee for several general and specialised mathematical journals and funding agencies.
- PhD student: Sultan Alzahrani (since 2018).

Ryan, Ray

Current research interests

Functional Analysis; Tensor Products of Banach Spaces and Banach lattices; Polynomials and Holomorphic Mappings on Banach Spaces and Riesz Spaces.

Recent publications

[1] C. Boyd, R.A. Ryan, S. Snigereva. Synnatzschke's theorem for polynomials *Positivity*, 25(1):144, 2021.

[2] C. Boyd, R.A. Ryan, S. Snigereva. Geometry of spaces of orthogonally additive polynomials on C(K). *J. Geometric Analysis*, 30(4), 2020.

[3] C. Boyd, R.A. Ryan, S. Snigereva. Radius of analyticity of analytic functions on Banach spaces. *J. Math. Anal. Appl.*, 463(1), 2018.

[4] J. Cruickshank, J. Loane, R.A. Ryan. Positive polynomials on Riesz spaces. *Positivity*, 21(3), 2017.

Seoighe, Cathal

Current research interests

Research interests include variation in somatic and germline mutation rates, genetic contributors to variation in gene expression and other molecular phenotypes and methods for the analysis of genomics data.

Recent publications

[1] O'Sullivan, B., and Seoighe, C. vcfView: An Extensible Data Visualization and Quality Assurance Platform for Integrated Somatic Variant Analysis. *Cancer Inform 19* (2020), 1176935120972377.

[2] Seoighe, C., Kiniry, S. J., Peters, A., Baranov, P. V., and Yang, H. Selection Shapes Synonymous Stop Codon Use in Mammals. *J Mol Evol 88*, 7 (09 2020), 549–561.

[3] Rainey, M. D., Bennett, D., O'Dea, R., Zanchetta, M. E., Voisin, M., Seoighe, C., and Santocanale, C. ATR Restrains DNA Synthesis and Mitotic Catastrophe in Response to CDC7 Inhibition. *Cell Rep 32*, 9 (09 2020), 108096.

[4] Cathomas, F., Azzinnari, D., Bergamini, G., Sigrist, H., Buerge, M., Hoop, V., Wicki, B., Goetze, L., Soares, S., Kukelova, D., Seifritz, E., Goebbels, S., Nave, K. A., Ghandour, M. S., Seoighe, C., ..., and Pryce, C. R. Oligodendrocyte gene expression is reduced by and influences effects of chronic social stress in mice. *Genes Brain Behav 18*, 1 (01 2019), e12475.

[5] Kong, Y., Rastogi, D., Seoighe, C., Greally, J. M., and Suzuki, M. Insights from deconvolution of cell subtype proportions enhance the interpretation of functional genomic data. *PLoS One 14*, 4 (2019), e0215987.

Research activities

- Primary supervisor of 5 and co-supervisor of 2 PhD students
- Scientific Director, SFI Centre for Research Training in Genomics Data Science
- SFI Principal Investigator Award to study sources of variation in mutation rates
- *Editorial board member of Annual Reviews in Biomedical Data Science* and *Briefings in Bioinformatics*

Simpkin, Andrew J.

Current research interests

My research focusses on longitudinal data analysis, functional data analysis, genomics and data science. In particular I'm interested in modelling high-throughput data such as those arising from sensor technologies.

Recent publications

[1] D Roshan, J Ferguson, C Pedlar, AJ Simpkin, W Wyns, F Sullivan, J Newell. A comparison of methods to generate adaptive reference ranges in longitudinal monitoring. *Plos one*, 16(2), 2021.

[2] G Bruinvels, E Goldsmith, R Blagrove, AJ Simpkin et al. Prevalence and frequency of menstrual cycle symptoms are associated with availability to train and compete: a study of 6812 exercising women recruited using the Strava exercise app. *British Journal of Sports Medicine*, 55(8), 438–443, 2021.

[3] R Mulder, A Neumann, CAM Cecil, E Walton, LC Houtepen, AJ Simpkin et al. Epigenome-wide change and variation in DNA methylation in childhood: Trajectories from birth to late adolescence. *Human Molecular Genetics*, 2021

Research activities

- Current research grants:
  Simpkin AJ, Bargary N (co-PIs). Functional data Analysis for Sensor Technology. SFI Frontiers for the Future project. December 2020 to November 2024; €467,569;
  Bargary N, Simpkin AJ (co-PIs). Statistical modelling of sensor technology data. SFI Confirm. March 2020 to August 2022. €190,146
- Graduate students: Beatrice Charamba, *Modelling continuous longitudinal glucose and heart rate data*; Daniel Gordon, *Developing specific training modalities to reduce injury incidence and optimise performance in football*, Massey University, NZ; Joe Gwatsvaira, *Functional data analysis for multivariate sensor data*, University of Limerick
- Presentations: Predicting and Individualising Training Load using historical GPS data in Elite Soccer. Sports Tomorrow Conference, Barcelona, September 2020; Covid Data Science, MedTech Forum, October 2020; Statistical Data Science, DSI seminar, April 2021
- External service: Secretary of the Irish Statistical Association; Statistical Editor: Euro intervention; Honorary Research Fellow, Bristol Medical School

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Tripathi, Bharat B.

Current research interests

My current research interest is in modeling and simulation of shear shock waves in brain in context of traumatic brain injury. This involves development of novel nonlinear continuum mechanics models, construction of state-of-the-art numerical algorithms like discontinuous Galerkin method, development of machine learning tools for optimization, prediction, calibration etc. In general, I am motivated to research in the field of computational mechanics to bring together the aspects of physics and mathematical/scientific computing with the theory of statistics. The amalgamation of the three for modeling propagation of information/material in biomedical applications, remains the overarching theme of his research.

Recent publications

[1] Sandhya Chandrasekaran, Francisco Santibanez, Bharat B. Tripathi, Ryan DeRuiter, and Gianmarco F. Pinton. In situ ultrasound imaging of shear shock waves in the porcine brain. *arXiv preprint arXiv:2104.11911*, 2021.

[2] Bharat Tripathi, Sandhya Chandrasekaran, and Gianmarco Pinton. Super-resolved shear shock focusing in the human head. *arXiv preprint arXiv:2010.03456*, 2020.

[3] Sandhya Chandrasekaran, Bharat B. Tripathi, David Espíndola, and Gianmarco Pinton. Modeling ultrasound propagation in the moving brain: applications to shear shock waves and traumatic brain injury. *IEEE Trans. Ultras., Ferr. Freq. Cont.*, **68**(1), 201-212, 2021.

[4] Bharat B. Tripathi, David Espindola, and Gianmarco F. Pinton. Modeling and Simulations of Two Dimensional Propagation of Shear Shock Waves in Relaxing Soft Solids, *J. Comput. Phys.*,**395**: 205-222, 2019.

[5] Bharat B. Tripathi, David Espindola, and Gianmarco F. Pinton. Piecewise parabolic method for propagation of shear shock waves in relaxing soft solids: one dimensional case, *Int. J. Numer. Meth. Biomed. Engg.* **35**(5):e3187, 2019.

Research activities

- Oral presentation in *6th Oxford International Neuron and Brain Mechanics Workshop* (April 19-20, 2021), Oxford, UK.
- Oral presentation in *2020 IEEE International Ultrasonics Symposium* (September 7-11, 2020), Las Vegas, USA.

Tuite, Michael

Current research interests

Vertex algebras and their intersection with analytic number theory, Riemann surfaces, lattice theory and group theory.

Recent publications

[1] Krauel, M., Mason, G., Tuite, M. and Yamskulna, G. Decompositions of index one Jacobi forms into $N = 4$ characters and formulas for mock modular forms. arXiv:2103.04561.

[2] Bringmann, K., Krauel, M. and Tuite, M. Zhu reduction for Jacobi n-point functions and applications. *Trans.AMS* 373(5) 3261–3293 (2020)

[3] Tuite, M. The Heisenberg generalized vertex operator algebra on a Riemann surface. arXiv:2006.01255. To appear in AMS Contemporary Mathematics.

[4] Krauel, M., Tuite, M. and Yamskulna, G. (Editors). *Vertex Operator Algebras, Number Theory and Related Topics* Contemporary Mathematics, Vol 753 (AMS 2020).

[5] Tuite, M. and Welby,M. General genus Zhu recursion for vertex operator algebras. arXiv:1911.06596

Research activities

- August 2019 Michael Flattery awarded a College of Science PhD Scholarship to work on "Vertex operators algebras at higher genus"
- Invited talks: Representation Theory XVI, Dubrovnik, Croatia June 1999; "Vertex operator algebras and relate topics", Chengdu, China 1999; UCD 2020; Illinois State University, USA 2020.

Yang, Haixuan

Current research interests

My focus is in Bioinformatics & Statistical Modelling, especially of network data such as protein-protein interactions, co-expression, and functional similarity. A bio-molecular network can be viewed as a collection of nodes, representing the bio-molecules, connected by links, representing relations between the bio-molecules. I am working on inferring valuable information from bio-molecular networks.

Recent publications

[1] M. Timilsina, A. Figueroa, M. d'Aquin, H. Yang. Semi-supervised regression using diffusion on graphs. *Applied Soft Computing*, 104:107188, 2021.

[2] M. Timilsina, D. Kernan, H. Yang, M. D'Aquin. Synergy Between Embedding and Protein Functional Association Networks for Drug Label Prediction using Harmonic Function. *EEE/ACM Transactions on Computational Biology and Bioinformatics*, doi: 10.1109/TCBB.2020.3031696, 2020.

[3] C. Seoighe, SJ Kiniry, A. Peters, PV Baranov, H. Yang. Selection shapes synonymous stop codon use in mammals. *Journal of Molecular Evolution*, 88(7):549-561, 2020.

[4] N. Zhou et al. The CAFA challenge reports improved protein function prediction and new functional annotations for hundreds of genes through experimental screens. *Genome Bioloigy*, 20:244, 2019.

[5] M. Timilsina, M. Tandan, M. d'Aquin, H. Yang. Discovering links between side effects and drugs using a diffusion based method. *Scientific reports*, 9: 10436, 2019.

Research activities

- With Mateo Torres, Alfonso E. Romero and Alberto Paccanaro, submitted a paper "Protein Function Prediction without experiments: going beyond sequence similarity for annotating bacterial genomes" to *Nature Machine Intelligence*.
- I was on sabbatical leave from Jan. 1, 2019 to Jun. 30, 2019.

Zurlo, Giuseppe

Current research interests

I am currently working on the modeling of a broad class of "surface growth" problems, where new mass is deposited in a prestressed state in layered patterns. Developing a mathematical model for surface growth will be relevant to better understanding many biological and non-biological processes, like additive manufacturing, biological growth or solidification. I am also interested in the modeling of instabilities in rubber cables, in the differential geometry of biological growth, in piezo- and electro-elasticity.

Recent publications

[1] Zaza D., Ciavarella M., Zurlo G., Strain incompatibility as a source of residual stress in welding and additive manufacturing, *Europ. J. Mech. A*, 85, 104147, 2021.

[2] Dolega M., Zurlo G., Le Goff M., Greda M., Verdier C., Joanny J.-F. , Cappello G., Recho P., Mechanical behavior of multi-cellular spheroids under osmotic compression, *J. Mech. Phys. Sol.*, 147 104205, 2021.

[3] Saccomandi G., Speranzini E., Zurlo G., Piezoelectric Machines: Achieving Non-Standard Actuation and Sensing Properties in Poled Ceramics, *Quart. J. Mech. Applied Math.* in press, 2021.

[4] Zurlo G., Blackwell J., Colgan N., Destrade M., The Poynting effect *Am. J. Phys.* 88, 1036, 2020.

[5] Truskinovsky L., Zurlo G. Nonlinear elasticity of incompatible surface growth *Phys.Rev. E* 99, 053001, 2019.

Research activities

- I have joined the Editorial Board for the journal Frontiers in Mechanical Engineering.
- I have supervised 2 MSc thesis of students from the Politecnico di Bari - Italy, as an occasion to collaborate with local experimentalists on welding and additive manufacturing.
- I take part to the PhD School in Structural and Geotechnical Engineering of the Università di Roma Tre - Italy, where on top of teaching a 20h module on nonlinear elasticity, I have several scientific collaborations.
- for my sabbatical leave (Jan-Jun 2021), in May 2021 I will be "visiting professor" of the

Università Sapienza in Roma - Italy, to interact scientifically with a local team on topics related to growth and solidification.

- I collaborate with Michel Destrade, of my same School, with whom we are currently writing a book and working on a new article on twisting rubber cords.
- I have an intense collaboration with Lev Truskinovsky, EPSCI Paris, with whom we work on surface growth models.
- I have refereed 20 articles.
- I have given 3 webinars in 2020 (Paris, twice in Roma) and 3 seminars (Venezia, Torino,Roma) in 2019.

6 Visitors

Voll, Christopher (Bielefeld University)
Visiting: Tobias Rossmann

Dates of visit: 5–19 May 2019
Research activity

We collaborated on a project devoted to ask zeta functions of modules of matrices defined in terms of support constraints. The reults of this work are documented in our paper *Groups, graphs, and hypergraphs: average sizes of kernels of generic matrices with support constraints* (arXiv:1908.09589). Christopher also gave a talk at Groups in Galway 2019. His stay was funded by the Irish Research Council and Science Foundation Ireland.

Dula, Giora (Netanya Academic College, Israel)
Visiting: Dane Flannery

Dates of visit: 21 May 2019–24 May 2019
Research activity

Constructing pairwise combinatorial designs (weighing matrices and their generalizations) via the novel theory of cohomology-developed matrices. Joint work with Assaf Goldberger, Tel Aviv University. School seminar, 23 May 2019.

Sentinelli, Paolo (Universidad de Chile)
Visiting: Angela Carnevale

Dates of visit: 16 June 2019 – 23 June 2019
Research activity

We worked on our joint project *k-Bruhat orders*, on a new family of poset structures defined on Coxeter groups. Paolo also gave a talk at our School seminar. His visit was supported by the *Irish Research Council*.

Kruael, Matt (California State University Sacramento)
Visiting: Michael Tuite

Dates of visit: 17 June 2019 – 22 June 2019
Research activity

Discussions on role of Mock modular forms in vertex operator superalgebras containing an $N = 4$ supeconformal subalgebra.

Cavaleri, Matteo (Niccolò Cusano University of Rome)
Visiting: Angela Carnevale

Dates of visit: 5 July 2019 – 13 July 2019
Research activity

We worked on a follow-up to our paper *Partial word and equality problems and Banach densities*. Matteo also gave a talk at our School seminar. His visit was part of an *Erasmus+ staff training project*.

Dobrinen, N. (University of Denver)
Visiting: A. McCluskey

Dates of visit: 10 August 2019 – 17 August 2019
Research activity

Discussion on proof technique and its application to establish main result in joint paper.

Brenti, Francesco (University of Rome - Tor Vergata)
Visiting: Angela Carnevale

Dates of visit: 3 September 2019 – 7 September 2019
Research activity

During Francesco's visit, we finalised our paper *Odd length: odd diagrams and descent classes*, which was recently published. Francesco also gave a talk at the *IMS September Meeting 2019* which took place at NUIG. His visit was supported by the *Irish Research Council*.

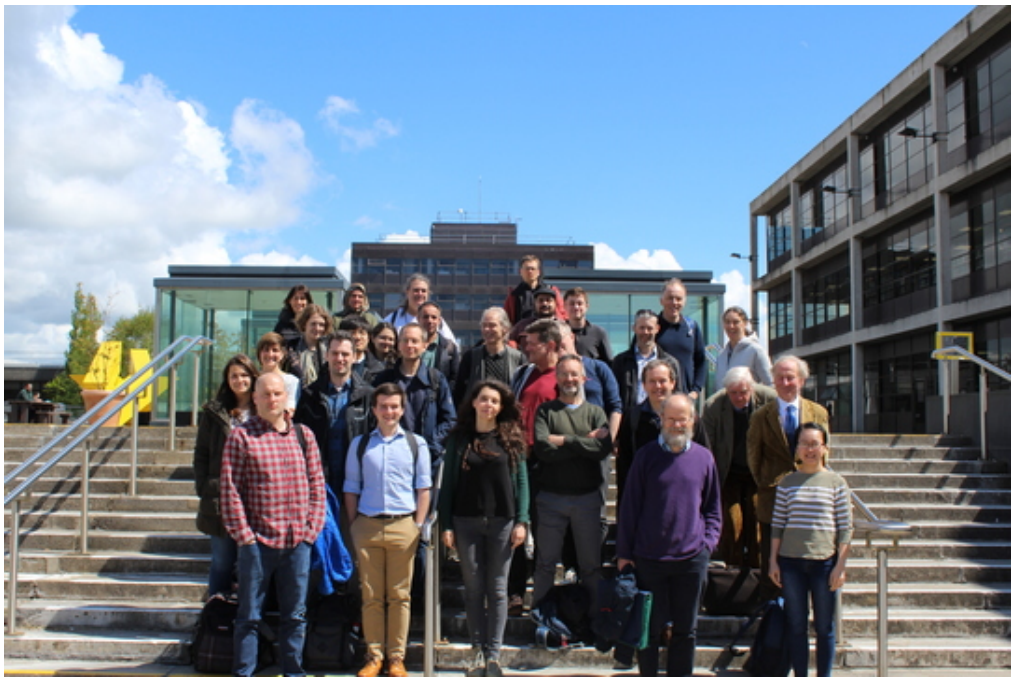
Ogden, Ray (University of Glasgow)
Visiting: Michel Destrade

Dates of visit: 05 September 2019 – 14 September 2019
Research activity

Worked on and completed a paper on 'Bending control and instability of functionally graded dielectric elastomers' with Yipin Su.

7 Conferences, meetings, and workshops

- **Groups in Galway 2019**
  Dates: 10–11 May 2019
  Speakers: Yiftach Barnea (Royal Holloway, University of London), Angela Carnevale (NUIG), Oihana Garaialde Ocaña (University of the Basque Country), Scott Harper (University of Bristol), Kevin Hutchinson (University College Dublin), H. Dugald Macpherson (University of Leeds), James D. Mitchell (University of St Andrews), Marta Morigi (University of Bologna), Christopher Voll (Bielefeld University)
  Organisers: Graham Ellis, Tobias Rossmann
  Funders: Science Foundation Ireland, the Office of the Registrar and Deputy President of NUI Galway, the Irish Mathematical Society
  Web page: `http://www.maths.nuigalway.ie/conferences/gig19/`



- **21st Galway Topology Colloquium**
  Dates: 26–28 June 2019
  Invited speakers: Paul Bankston (Marquette University, Milwaukee), KP Hart (TU Delft), Michael Hrusak (Morelia), Paul Szeptycki (Toronto), Ittay Weiss (Portsmouth)
  Organisers: Jorge Bruno (University of Winchester), Aisling McCluskey (NUI Galway)
  Funders: University of Winchester
  Web page: `https://sites.google.com/view/gtc21/home`

- **FPSAC 2020 Online**
  Dates: 6 July – 24 July 2020
  Organisers: Alejandro Morales (University of Massachusetts Amherst), Dan Betea (KU Leuven) Sara Billey (University of Washington), Angela Carnevale (National University of Ireland, Galway), Laura Colmenarejo (University of Massachusetts Amherst), William Dugan (University of Massachusetts Amherst), Christian Gaetz (MIT), Sean Griffin (University of Washington), Helen Jenne (University of Oregon), Jang Soo Kim (Sungkyunkwan University), Matjaž Konvalinka (University of Ljubljana & IMFM), Vivien Ripoll (Solving Fun), Nicolas M. Thiéry (Université Paris-Saclay)
  Web page: `https://sites.google.com/view/fpsac2020online/home`

- **Launch conference of the SFI Centre for Research Training in Genomics Data Science**
  Date: 3 September 2019
  Speakers: Anton Nekrutenko, Ken Wolfe, Douwe van Sinderen, Orla Hardiman, Shamil Sunyaev, Eimear Kenny, Aoife McLysaght, Remco Loos, Mark Lawler, Ines Thiele, Anthony Ryan, Jochen Prehn
  Organisers: Sandra Healy, Cathal Seoighe
  Funder: Science Foundation Ireland
  Web page: `https://genomicsdatascience.ie/launch-conference/`

- **CRT Annual Research Symposium**
  Dates: 3–4 December 2020
  Speakers: Thomas Schwarzl, Vivane Slon, Uri Alon, Casey Greene, Yvan Saeys, Eimear Kenny
  Organisers: Sarah Ennis, Shane O'Connell, Lydia King (NUIG) and Annabelle Nwaokorie, Cian D'Arcy, James Ward, Martina Kreileder, Sam Carthy, Sarah Lussoso, Swathi Upadhya (UCD)
  Funders: Science Foundation Ireland

- **Groups in Galway 2020 — Online edition**
  Dates: 9–11 September 2020
  Speakers: Matteo Cavaleri (Niccolò Cusano University Rome), Joanna B. Fawcett (Imperial College London), Meinolf Geck (University of Stuttgart), Radhika Gupta (University of Bristol), Joshua Maglione (Bielefeld University), John Murray (Maynooth University), Emily Norton (TU Kaiserslautern), Anitha Thillaisundaram (University of Lincoln)
  Organisers: Angela Carnevale, Tobias Rossmann
  Funders: Irish Mathematical Society
  Web page: `http://www.maths.nuigalway.ie/conferences/gig20/`

- **Irish Geometry Seminar**
  Dates: February–May 2021
  Speakers: Wolfgang Ziller (University of Pennsylvania, USA), Anna Siffert (WWU Münster, Germany), Claude LeBrun (Stony Brook University, USA), Ben McKay (UCC), Jonathan Wermelinger (University of Fribourg, Switzerland), Masoumeh Zarei (Universität Augsburg, Germany), Fernando Galaz-García (Durham University, UK), Joel Fine (Université Libre de Bruxelles, Belgium), Martin Kilian (UCC), John Harvey (Swansea University, UK), Renato G. Bettiol (City University of New York, USA), Carolyn Gordon (Dartmouth College, USA)
  Organisers: Martin Kerin (NUIG), David Wraith (Maynooth), Mark Walsh (Maynooth)
  Web page: `http://www.maths.nuigalway.ie/~kerin/irishgeomseminar.shtml`

- **Maths Support in Covid Times**
  Dates: 24 June 2020, 23 September 2020, 21 January 2021, 19 May 2021
  Organisers: Kirsten Pfeiffer (NUIG), Julie Crowley (MTU Cork)
  Web page: `http://www.imlsn.ie/index.php/past-events/maths-support-in-covid-times-workshops`

8 School seminars and reading groups

Regular Seminars

- School Seminar (list of talks below)
- Bioinformatics seminar series/journal club
- Linear Algebra Seminar
- Statistics Reading Group
- Reading group: The field with one element (2019/2020)
- Reading group: Combinatorics (2020/2021)
- Postgraduate Modelling and Applied Mathematics Research Group Talks
- Postgraduate Seminar Group (list of talks below)

School Seminars

[1] Eoin O Colgain, Asia Pacific Center for Theoretical Physics, South Korea. *Classical Yang-Baxter Equation from Gravity*, 17/1/2019. (Contact: Michael Tuite)

[2] Caroline Brophy, Maynooth University. *Modelling data from biodiversity experiments*, 24/1/2019. (Contact: John Newell)

[3] Pilar Rueda, University of Valencia, Spain. *The biduality problem in spaces of analytic functions*, 25/1/2019. (Contact: Nina Snigireva & Raymond Ryan)

[4] John Cosgrave. *Gauss factorials, and Gauss primes (joint work with Karl Dilcher)*, 21/2/2019. (Contact: Michael Tuite)

[5] Bernd Schulze, Lancaster University, UK. *Rigidity of bar-joint frameworks with coordinated constraint*, 28/2/2019. (Contact: James Cruickshank)

[6] Nikolaos Pantelidis, Waterford Institute of Technology. *On the Riordan Group and the almost-Riordan Group*, 7/3/2019. (Contact: Kevin Jennings)

[7] Paulo Lisboa, Liverpool John Moores University, UK. *Good Practice with Machine Intelligence for Real-World Data*, 21/3/2019. (Contact: John Newell)

[8] Michael Beverland, Microsoft Seattle, US. *Microsoft Quantum*, 28/3/2019. (Contact: Mark Howard)

[9] Vincent Gélinas, TCD. *An Evens-Golod-Venkov theorem for finite-dimensional monomial algebras*, 28/3/2019. (Contact: Emil Skoldberg)

[10] Giuseppe Tomassetti, Università di Roma Tre, Italy. *Macroscopic and microscopic behavior of narrow elastic ribbons*, 3/4/2019. (Contact: Zurlo Giuseppe)

[11] Padraig Ó Catháin, Worcester Polytechnic Institute, US. *Morphisms of Complex Hadamard matrices*, 8/4/2019. (Contact: Tobias Rossmann)

[12] Damien Woods, Maynooth University. *Molecular computing with DNA self-assembly: Theory and implementation*, 11/4/2019. (Contact: Cathal Seoighe)

[13] Vakhtang Putkaradze, University of Alberta, Canada. *Theoretical figure skating*, 25/4/2019. (Contact: Michael Tuite)

[14] Sofia Ortega Castillo, CIMAT, Mexico. *Analytic-geometric phenomena in several complex variables*, 7/5/2019. (Contact: Ray Ryan)

[15] Romina Gaburro, University of Limerick. *Calderón's inverse conductivity problem and its applications to imaging*, 16/5/2019. (Contact: Michel Destrade)

[16] Alexander Guterman, Lomonosov Moscow State University, Russia. *Permanent functions and the resolution of the Krauter*, 22/5/2019. (Contact: Rachel Quinlan)

[17] Giora Dula, Netanya Academic College, Israel. *Families of weighing matrices found using group cohomology*, 23/5/2019. (Contact: Dane Flannery)

[18] Alfredo Marzocchi, Università Cattolica del Sacro Cuore, Italy. *The Kirchhoff-Plateau problem and some applications*, 28/5/2019. (Contact: Michel Destrade)

[19] Colm Mulcahy, Spelman College, USA. *A Century of NUI Travelling Studentships: the Galway story*, 30/5/2019. (Contact: Michel Destrade)

[20] Paolo Sentinelli, Universidad de Chile, Chile. *Parabolically induced functions and equidistributed pairs*, 17/6/2019. (Contact: Angela Carnevale)

[21] Matt Krauel, Sacramento State University, US. *Some questions surrounding representations of vertex operator algebras*, 20/6/2019. (Contact: Michael Tuite)

[22] Matteo Cavaleri, Niccolò Cusano University, Italy. *Wreath product of graphs and centrality measures*, 11/7/2019. (Contact: Angela Carnevale)

[23] Brigitte Servatius, Worcester Polytechnic Institute, US. *Matroids, delta-matroids, maps, and rigidity matroids*, 12/9/2019. (Contact: James Cruickshank)

[24] Niall Madden, NUIG. *Balanced norms for boundary layer problems: if you can't see it, you can't compute it.*, 19/9/2019.

[25] Aisling McCluskey, NUIG. *Classifying closed subsets of the reals*, 3/10/2019. (Contact: Michael Mc Gettrick)

[26] Martin Kerin, NUIG. *Double disk-bundles in geometry and topology*, 10/10/2019. (Contact: Haixuan Yang)

[27] Martin Stynes, Beijing Computational Science Research Center, China. *Time-fractional differential equations and their numerical solution*, 17/10/2019. (Contact: Niall Madden)

[28] Tony Nixon, Lancaster University, UK. *Global rigidity of linearly constrained frameworks*, 24/10/2019. (Contact: James Cruickshank)

[29] Harold Berjamin, NUIG. *Modelling wave propagation in solid materials with memory*, 14/11/2019. (Contact: Michel Destrade)

[30] Yinan Li, Centrum Wiskunde & Informatica, Netherlands. *Average-case Algorithm for Testing Pseudo-Isometry of Alternating Matrix Tuples*, 21/11/2019. (Contact: Tobias Rossmann)

[31] Klara Stokes, Maynooth University. *Configurations of points and lines and graphs on surfaces*, 28/11/2019. (Contact: Emil Sköldberg)

[32] Michael Mc Gettrick, NUIG. *GLUAS, Infeasible Regions and Generalized Voronoi Diagrams*, 5/12/2019. (Contact: Michael Mc Gettrick)

[33] Ciaran Mac an Bhaird, Maynooth University. *Algorithm's al-jabr*, 16/1/2020. (Contact: Kirsten Pfeiffer)

[34] John S. Butler, Technological University Dublin. *How the brain processes self-motion*, 30/1/2020. (Contact: Pilib Ó Broin)

[35] Bin Wu, NUIG. *Electrostatically tuneable dynamic characteristics of soft electro-active materials*, 6/2/2020. (Contact: Michel Destrade)

[36] Petri Piiroinen, NUIG. *Twists and turns during my sabbatical: part 2*, 13/2/2020.

[37] Lennon O'Naraigh, UCD. *Thermal Science meets Mathematical Modelling - opportunities for Applied Mathematics*, 20/2/2020. (Contact: Michel Destrade)

[38] Jacopo Ciambella, Sapienza Università di Roma, Italy. *Nonlinear anisotropic viscoelasticity of soft materials*, 27/2/2020. (Contact: Giuseppe Zurlo)

[39] James Cruickshank, NUIG. *Symmetric configurations of line segments*, 26/3/2020.

[40] Nicole Beisiegel, UCD. *An Adaptive DG Model for Extreme Waves*, 23/4/2020. (Contact: Niall Madden)

[41] Colm Mulcahy, Spelman College, US. *One, Two, Many (or, a dozen reasons why mathematics isn't as easy as 1,2,3)*, 28/5/2020.

[42] Alain Goriely, University of Oxford, UK. *The surprising shape of planets*, 2/6/2020. (Contact: the Stokes Workshop)

[43] Sarah Muldoon, the University at Buffalo (SUNY), US. *Personalized Brain Network Models*, 2/6/2020. (Contact: the Stokes Workshop)

[44] Krishnan Shankar, Oklahoma/NSF, US. *A Mathematical Exploration*, 11/6/2020. (Contact: Martin Kerin)

[45] Andrew Lobb, Durham University, UK. *The smooth rectangular peg problem*, 18/6/2020. (Contact: Martin Kerin)

[46] Haixuan Yang, NUIG. *A Heat Diffusion Model on a graph with boundary conditions and its Applications*, 8/10/2020.

[47] Peter Clarkson, University of Kent, UK. *Some reflections on Athena SWAN*, 12/11/2020. (Contact: Niall Madden)

[48] Dúalta Ó Fionnagáin, NUIG. *Modelling the winds of low-mass stars like our Sun*, 19/11/2020.

[49] Bharat Tripathi, NUIG. *On Modelling and Simulation of Nonlinear Waves for Biomedical Problems*, 26/11/2020.

[50] Michael Tuite, NUIG. *Vertex operator algebras and a generalized MacMahon master theorem*, 3/12/2020.

[51] Viola Siconolfi, Bielefeld University, Germany. *Ricci curvature, graphs and Coxeter groups*, 10/12/2020. (Contact: Angela Carnevale)

Postgraduate Seminar Group

The Postgraduate Seminar Group is a virtual seminar group for postgraduate students in The School of Mathematics, Statistics & Applied Mathematics, NUI Galway. Group meetings will resume next semester, and will be held at 12pm midday every second Friday. Meetings will consist of two short seminars of roughly 10–15 minutes each, followed by about 5 minutes for Q&A. If you would like to be added to the mailing list, please contact one of the organisers: Victoria Sánchez Muñoz or Peter Phelan.

[1] Peter Phelan, *Parity binomial edge ideals with pure resolutions*, 05/03/2021

[2] Róisín Hill, *Generating layer adapted meshes using mesh PDE's*, 05/03/2021

[3] Victoria Sánchez Muñoz, *A friendly introduction to Quantum Games*, 19/03/2021

[4] Roberto Galizia, *Exploiting individual agent properties for analysis and control of collective network evolution*, 09/04/2021

[5] Aoife Hill, *Modelling of biodegradable polymers for biomedical applications*, 16/04/2021

[6] Sultan Alzahrani, *Relation Modules and Ask Zeta Functions*, 30/04/2021

9 SIAM Student Chapter

The NUI Galway Student Chapter of SIAM, the Society for Industrial and Applied Mathematics, aims to bring together students and researchers from across campus to generate interest in applied mathematics, share ideas, and develop leadership skills. Members are drawn from a range of disciplines, including pure and applied mathematics, computer science, physics and engineering. The current officers and committee (2020/2021) are

President: James Blackwell

Vice President: Róisín Hill

Secretary: Michael Flattery

Treasurer: Victoria Sánchez Muñoz

Faculty Advisor: Niall Madden

Committee members: Aoife Hill, Sophie Plunkett, Maxwell Paganga, Pearce Harney-Nolan, Kelvin Killeen.

Since the last booklet, the Chapter activities included:

27-30/05/2019 Chapter members assisted in organising and running the fifth Annual Stokes Modelling Workshop for undergraduates.

10-11/06/2019: Six chapter members attended the SIAM UKIE National Student Chapter Conference 2019 at the University of Manchester, contributing five talks and two posters.

13/06/2019 Annual General Meeting.

Figure 1: Members of the NUI Galway SIAM Student Chapter attending the UKIE Annual Student Chapter Conference in 2019

11/2019: For the 2019 Galway Science and Technology Festival, the Chapter ran several Build it and Cut it: Fun with Shapes workshops, both in primary schools and at the Exhibition Day on the 24/11/2019.

06/12/2019: The Chapter hosted the sixth annual Irish SIAM Student Chapter Conference. More that thirty participants from across Ireland attended the conference, and Bram Siebert, a former NUI Galway undergraduate, won the prize for the best presentation.

02-05/06/2020 Chapter members assisted in organising and running the sixth Annual Stokes Modelling Workshop for undergraduates.

12/06/2020 Annual General Meeting.

06-07/07/2020: Three Chapter members virtually attended the SIAM Annual Meeting AN20, originally to be held in Toronto, Canada. James Blackwell was the Chapter Representative and took part in the SIAM Student Chapter mixer event.

04/12/2020: Four Chapter members attended the SIAM Irish Student Chapter Conference organised by SIAM-IMA Dublin Area Student Chapter. Faiza Alssaedi and Róisín Hill presented their work, with Róisín jointly winning prize for best presentation!

12/12/2020: The NUI Galway Mathematics Society and our Chapter co-hosted a (surprisingly difficult!) table quiz attended by members of both groups and other undergraduate students.

23/03/2021: On World Meteorological Day, we hosted a talk by Eoin Moran, Director of Met Éireann and former Mathematics graduate of NUI Galway. His talk, titled "Predicting the weather and future climate scenarios", was very well received with over 60 attendees. Later that day, Róisín Hill was a panellist in a PhD Panel Discussion: The Life of a PhD Student, organised by SIAM-IMA Dublin Area Student Chapter.

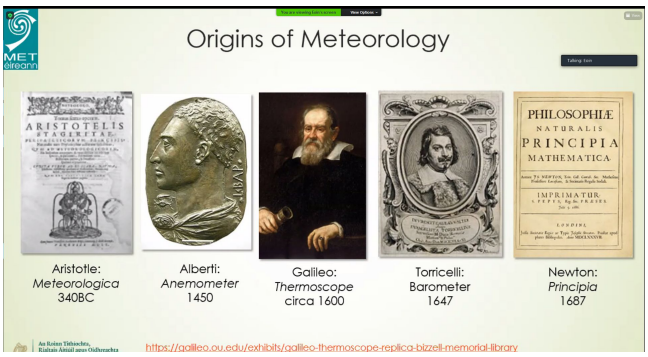


Figure 2: A slide from Eoin Moran's presentation